PLAN FOR THE RECOVERY OF DESERT BIGHORN SHEEP IN NEW MEXICO 2003-2013

New Mexico Department of Game and Fish
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❖ Executive Summary

Desert bighorn sheep (*Ovis canadensis mexicana*) were once prolific in New Mexico, occupying most arid mountain ranges in the southern part of the state. Over-hunting, and disease transmission from livestock are 2 primary reasons for the dramatic decline in bighorn sheep numbers throughout the west during the early 1900s. In 1980, desert bighorn were placed on New Mexico's endangered species list. From 1992-2003, approximately 25% of bighorn were radiocollared to learn causes of mortality driving this species towards extinction. Approximately 85% of all known-cause non-hunter killed radiocollared individuals have been killed by mountain lions. Despite the lack of a native ungulate prey base in desert bighorn range, mountain lion populations remain high, leading to the hypothesis that mountain lions are subsidized predators feeding on exotic ungulates, including cattle. Lack of fine fuels from cattle grazing have resulted in a lack of fire on the landscape. This has lead to increased woody vegetation which inhibits bighorn's ability to detect and escape from predators. Bighorn numbers in spring 2003 in New Mexico totaled 213 in the wild, and 91 at the Red Rock captive breeding facility. This is in spite of releasing 266 bighorn from Red Rock and 30 bighorn from Arizona between 1979 and 2002. Several existing herds of desert bighorn likely need an augmentation to prevent them from going extinct. The presence of domestic sheep and Barbary sheep, which pose risks to bighorn from fatal disease transmission and aggression, respectively, preclude reintroduction onto many unoccupied mountain ranges. Numerous federal agencies, private landowners, sportsmen's groups, environmental groups, and other private organizations involved with and interested in desert bighorn management make recovery of this species a cooperative effort.

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❖ Acknowledgements

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❖ Introduction

This is a plan to guide the New Mexico Department of Game and Fish (NMDGF) in recovering desert bighorn sheep from 2003 through 2013. Issues and strategies are identified that will contribute to achieving a goal of effectively managing desert bighorn sheep to increase population numbers such that they may be removed from the state endangered species list. From 1995-2002, *New Mexico's Long Range Plan for Desert Bighorn Sheep Management* was the guiding document for management practices. With the expiration of that plan, this Recovery Plan was written. It serves as a long range plan, but also satisfies the requirements of the New Mexico Wildlife Conservation Act which details steps to down list or delist a species from the state endangered species list. This plan is intended as a broad scale document and as such is not specific in nature. Detailed accounts of specific projects are documented elsewhere. The dynamic nature of wildlife has the potential to change the species status and modify the challenges facing desert bighorn sheep. A biennial review of this document is planned so that it may be kept current.

❖ Natural History

Mexican desert bighorn sheep (*Ovis canadensis mexicana*) weigh between 3 and 5.5 kg at birth (Krausman and Shackleton 2000). Adult rams in New Mexico can weigh up to 100 kg, and ewes up to 65 kg (NMDGF Capture Data Sheets). Rams' horns are much larger ewes' and are their primary distinguishing feature. Desert bighorn sheep vary from pale beige to chocolate brown and have a characteristic white rump patch. In 1998, an estimated 22,500 desert bighorn sheep inhabited the desert mountain ranges of the southwestern United States and Mexico (Toweill and Geist 1999). The subspecies found in New Mexico (*O. c. mexicana*) range from New Mexico west to southern Arizona, and south to Sonora, Mexico. The type-specimen was collected in Chihuahua, Mexico, however bighorn are extinct in the wild in Chihuahua. Mexican desert bighorn number about 3,000 in Arizona (Wakeling, AZGF pers. comm.), approximately 2,000 in Mexico (Toweill and Geist 1999), and 213 in New Mexico (as of spring 2003) (NMDGF Survey Files 2003).

Habitat Requirements. The most important habitat requirement of desert bighorn sheep is open, mountainous, or canyon habitat, close to escape terrain (minimum of 60% slope). Bighorn rely on keen eyesight and open terrain to detect predators and elude them by fleeing to escape terrain where predators are not as agile. Escape terrain is particularly important for ewes during parturition and while rearing lambs. The amount of habitat available to desert bighorn sheep is ultimately determined by the amount of escape terrain close to open landscapes (McCarty and Bailey 1994).

In the Chihuahuan desert of New Mexico, shrubs dominate the diet of desert bighorn, but they eat a wide range of plants and vary their selection based on the most nutritious plants available seasonally (Sandoval 1979a, Bavin 1982). For example, bighorn favor newly emergent grasses and forbs during the summer-fall rainy season whereas use of shrubs is greatest in winter and

early spring as grass and forb quality declines. High quality and diversity of available plants are considered important to desert bighorn sheep (Sandoval 1979a, Bavin 1982).

Water is used by desert bighorn year-round (Gunn 2000). In New Mexico, most bighorn are found within 1 mile of water and stay closer during hot, dry weather (Sandoval 1979a, Bavin 1982), but consistent use of watering sites by bighorn is not necessarily observed (Barnitz, BLM wildlife biologist, pers. comm.). Although some indigenous populations may have depended solely upon ephemeral water sources and succulent plants (Watts 1979), water may be used when provided. Bighorn have been observed using free-water in all New Mexico populations including Red Rock, and it may be an important factor in home range selection (McCarty and Bailey 1994).

Ecological Role. Desert bighorn sheep are 1 of just 4 native ungulates inhabiting desert mountain ranges. Desert mule deer *Odocoileus hemionus eremicus*) are sympatric with desert bighorn in all ranges in New Mexico. Coues' white-tailed deer (*O. virginianus couesi*) and collared peccary (*Tayassu tajacu*) occur in a portion of New Mexico desert bighorn sheep ranges. Morphological and physiological adaptations enable desert bighorn to exploit a unique niche within desert ecosystems. The preference for steep terrain is a defining characteristic of desert bighorn sheep habitat. Waste excreted by bighorn help fertilize vegetation and return nutrients back to the soil. In a balanced ecosystem, bighorn serve as prey for predators who in turn may prevent bighorn populations from exceeding carrying capacity.

Reproduction. Desert bighorn are capable of breeding at 18 months of age (Turner and Hansen 1980), and ewes give birth to 1 lamb after a gestation period of 6 months. In New Mexico, desert bighorn have been documented lambing at 2 years of age in the Fra Cristobal Mountains (Parsons and Kunkel 1999). Most lambs are born between January and March, although desert bighorn have been reported to be born every month of the year. An extended lambing season is advantageous in unpredictable desert environments where adverse conditions could eliminate an entire lamb crop if they were born during only 1 month. Ewes care for the young, and rams generally remain separate from ewe-lamb groups with the exception of during the rut. The highest mortality rate generally occurs in the first year, however, if desert bighorn survive their first year they have the potential to reach 10-14 years of age (Turner and Hansen 1980), or older (NMDGF Capture Records, NMDGF Mortality Tables).

General Habits. Desert bighorn sheep are social animals that live in groups most of the year. The largest groups are found during the peak of the breeding or rut period between July and September when rams and ewes gather on the same range. After the rut, adult rams generally segregate from ewe-lamb groups. These bachelor ram bands often use gentler habitats with more abundant forage to optimize nutrient intake and therefore enhance body condition and horn growth. This ultimately leads to increased reproductive fitness. In contrast, ewes spend more time in steep rocky escape terrain to maximize protection from predators and to help ensure lamb survival. These areas generally have less abundant forage (Bleich et al. 1997).

Unlike other ungulates with high juvenile dispersal rates, bighorn transfer home range knowledge from one generation to the next and rarely re-colonize ranges where they have been

extirpated. Rams may move long distances between mountain ranges in search of ewes during the rut, but they will return to their natal home if they do not find other bighorn, and ewes rarely follow rams on these journeys (Geist 1971). Generally, transplants are necessary to establish resident populations at new sites, especially if inter-mountain corridors contain barriers to successful movement and colonization. However, occasionally individual bighorn are highly exploratory, i.e., dispersal phenotypes (Geist 1971) and may establish metapopulations through intermountain movements. A population of desert bighorn is defined as inhabiting a discrete mountainous area. A metapopulation is a group of populations that potentially have genetic interchange and/or provide demographic support needed to repopulate an area if a dieoff occurs. These intermountain movements may reestablish patterns that were lost when populations were extirpated, and enhance genetic and demographic support that is vital for persistence of small populations. Management of movement corridors between populations is critical to ensure long-term persistence of desert bighorn and will entail more extensive coordination among agencies and landowners than management of single populations (Bleich et al. 1990, Bailey 1992).

❖ Historical Perspective

Historically, desert bighorn sheep probably occurred in most arid mountain ranges in southern and central New Mexico (Table 1). Evidence of their occupation is available for 14 ranges (Buechner 1960). During the settlement of New Mexico, desert bighorn populations declined rapidly due to illegal hunting and competition and diseases introduced by domestic livestock (Buechner 1960). The decline roughly followed a geographic north-south trend that correlates with the progressive movement of man and livestock. Spanish settlers introduced domestic sheep into the Rio Grande Valley in the mid-1500's, and the Navajo and Pueblo people adopted sheep herding. This spread the impacts of domestic sheep, primarily by spreading pneumonia that is usually fatal for bighorn, throughout central and northern New Mexico. These flocks of sheep were huge, totaling an estimated 3 million animals by 1820 (Savage and Swetnam 1990). Between 1860-1900 large-scale cattle operations controlled the open range in southern New Mexico and desert grasslands deteriorated to desert shrub (Dick-Peddie 1993). Subsequently, many large cattle companies disbanded and homesteaders and other landowners converted stock to domestic goats and sheep (Denevan 1967, Dick-Peddie 1993). By the early 1900's, most desert bighorn populations were extinct, and by 1946 only the San Andres and Big Hatchet populations remained.

Bighorn hunting was prohibited in 1889, but uncontrolled market hunting continued to be an important cause of mortality in some areas. In the early 1900's, 40 desert bighorn sheep were brought to a Deming meat market from the West Potrillo Mountains, 32 bighorn were killed in the Guadalupe Mountains, and 20 bighorn were killed in the Hatchet Mountains (Mearns 1907, Lang 1956, Buechner 1960). State Game Refuges were established in the Hatchet and Guadalupe Mountains during the mid-1920's in the belief that if bighorn were protected from illegal killing they would increase and colonize former ranges (Ligon 1927). Livestock were not prohibited in the refuges. Severe grazing exacerbated by the 1950's drought contributed to the decline of the Hatchet bighorn from an estimated 125 bighorn to less than 15 by 1978 (Gross 1960, Buechner 1960, Lenarz 1978, Watts 1979). Diseases and overgrazing introduced by

Table 1. Historic evidence of desert bighorn sheep in New Mexico.

Estimated Time of Pop. Loss		Historic Evidence of Existence[1]
Prior to 1800		
1.	Zuni Mountains	Coronado saw sheep in 1540 (Buechner 1960); Horns found (Bailey 1931).
2.	Magdalena Mountains	No sight records; horns found (Bailey 1931).
1850-1900		
3.	San Francisco River	James Pattie saw "multitudes" in 1825 (Buechner 1960).
4.	Turkey Creek	3 killed in 1849 (Buechner 1960).
5.	Burro Mountains[2]	Ram killed in 1900 (Bailey 1931). Locals have skulls (Gordon 1957).
Early 1900's		
6.	Alamo Hueco Mountains[2]	Numerous horns found and ram killed in 1893 (Mearns 1907). A ram joined domestic sheep flock in 1898 (Gordon 1956). Transient groups sighted (moving from Big Hatchet and Peloncillo mountains) between 1915-1977 (Sandoval 1982).
7.	Animas Mountains	Horns and "plentiful" sign in 1893 (Mearns 1907). Seven bighorn sighted by BLM in 1981 on east side (Sandoval 1982).
8.	Peloncillo Mountains[2]	Report of sheep in 1906 (Bailey 1931) and 1908 (Sandoval 1982).
9.	West Potrillo Mountains	40 killed in 1900 (Hornaday 1901, quoted by Buechner 1960).
1940's-1950's		
10.	Guadalupe Mountains	100 estimated in 1916 by J.S. Ligon (Bailey 1931). Dead ram found in Peñasco Canyon in 1946 (Sandoval 1982). Last reliable sighting of sheep was in 1946 (Lang 1956).
11.	Sacramento Mountains	Sightings 1936-1942 (Sandoval 1982); fresh head sent to NMGF in 1942 (Sands 1967), possibly same one killed on Mescalero Reservation in 1942 (Holtz 1943).
12.	El Malpais	Bighorn last observed in 1950's by Ramah Navajo; skeletal remains carbon dated 1950-55 (Carlton 1993). Considered desert bighorn based on morphometic analyses of 4 skulls (Wehausen and Ramey 1994).
Extant Populations		
13.	Big Hatchet Mountains	(Mearns 1907).
14.	San Andres/Organ Mtns.	(Reviewed by Buechner 1960, Sandoval 1979b).

[2]Quarternary bighorn fossils have been found at 5 sites in New Mexico including caves in the Black Range, Guadalupe Mountains and Sacramento Mountains (Harris 1993).

[1]Mearns (1907) included what is now known as the Alamo Hueco Mountains with the Dog Mountains, the Animas with the San Luis Mountains, and the Peloncillo with the Cloverdale Range. The Burro Mountains were also known as the Carlisle and White Rock Range.

domestic sheep and goats, overgrazing, and continued illegal hunting (Snow and Zimmerman 1939) contributed to the extirpation of the Guadalupe bighorn by 1946 (Gross 1960).

The declining trend of desert bighorn in New Mexico prompted the establishment of the San Andres National Wildlife Refuge (SANWR) in 1941 and the propagation of a captive desert bighorn herd at the Red Rock Wildlife Area (Red Rock) in 1972. In 1980, the State Game Commission added desert bighorn to the state list of endangered wildlife, pursuant to the New Mexico Wildlife Conservation Act (WCA) (NMSA 17-2-37 through 17-2-46, 1995 compilation). An endangered species is defined as one whose prospects of survival or recruitment within the state are in jeopardy. In 1988, the listing was restricted to populations indigenous to New Mexico in order to be consistent with the WCA's directive to "develop a list of those species indigenous to the state determined to be threatened or endangered…" (17-2-41 NMSA 1978). The captive Red Rock herd and Peloncillo Mountain population, which included founding stock from Arizona, were delisted (NMDGF 1988). Since its establishment, Red Rock has been the source herd for the vast majority of transplants to augment and establish desert bighorn herds in New Mexico.

Causes of Decline. One hundred years ago, livestock grazing, domestic sheep herds, and uncontrolled market hunting threatened the existence of bighorn sheep. Changes in regulations and resource use practices have altered the severity of some of these threats while creating new ones. The establishment of large scale cattle operations and increased deer numbers caused an increase in mountain lion numbers (*Puma concolor*) in the west (Berger and Wehausen 1991). Bighorn and mountain lions presumably coexisted when mountain lion numbers were low. Drought and predation have recently caused many deer populations in desert ranges to decline (Logan et al.1996), but increased mountain lion numbers have lead to an increased occurrence of predation on bighorn sheep (Berger and Wehausen 1991). Mountain lions are able to prey switch onto other food sources and therefore mountain lion populations do not appear to have declined following the decrease in deer numbers. Bighorn sheep are one alternative food source for mountain lions that is suffering the negative impacts of an artificially elevated number of mountain lions in the ecosystem.

Currently, mountain lion predation and habitat degradation from extensive livestock grazing and fire suppression are among the most significant threats. These conditions, in combination with desert bighorn's inherently low rate of increase, difficulty in colonizing new habitat (intensified by modification and human development of potential inter-mountain movement corridors), sensitivity to diseases, and competition with humans and livestock for resources, exacerbate bighorn's inability to increase in number. Consequently, recovery of desert bighorn will take extraordinary effort. Through radiocollaring efforts over the past 10 years, it has been documented that approximately 85% of all known-cause non-hunter related mortalities of radiocollared wild desert bighorn in New Mexico are due to mountain lion predation. This is an example of top-down regulation, meaning that bighorn numbers are limited by predation, not by forage availability or habitat quality. Therefore, available occupied habitat could support additional bighorn.

❖ Population Summaries

In spring 2003, 304 desert bighorn sheep (including 91 in Red Rock) were estimated in New Mexico. This is a decline from an estimated 360 (including 114 in Red Rock) in 1994, despite the release of 185 bighorn (67 ewes, 95 rams, and 3 lambs from Red Rock from 1995-2002, 18 ewes and 2 rams from Arizona in 2002) (NMDGF Red Rock Table 2003) (Table 2). Population estimates as of spring 2003 were: 91 in Red Rock, 70 in the San Andres, 25 in the Sierra Ladron, 25 in the Peloncillos, 35 in the Hatchets, and 58 in the Fra Cristobals (these estimates include a minimum of 40 spring lambs in wild populations and 23 lambs in Red Rock) (Figure 1). The Alamo Hueco population is considered extinct with occasional transient bighorn from the Big Hatchet Mountains. The Animas population, which self-started in 1996, declined to 6 individuals in 2000 and no bighorn were observed from 2001 to 2003, is also considered extinct.

Red Rock (Table 3). In 1972, NMDGF established fenced pastures at Red Rock to propagate desert bighorn sheep for subsequent releases into the wild. Twenty-two bighorn from the San Andres Mountains and the Loma Prieta Range in Sonora, Mexico formed the nucleus of the herd. The original 182 hectare pasture was increased to 526 fenced hectares in 1990 (Rominger 1997), also increasing Red Rock's carrying capacity. Red Rock bighorn primarily feed on natural vegetation, are exposed to predators, and freely roam over 5 km^2 of canyons, springs, and steep slopes (Rominger 1997). Since its establishment in 1972, the Red Rock herd has increased almost every year bighorn were not removed. Between 1986 and 1990, and in 1994, 1995, and 1997, the herd showed an annual increase of 25%, close to the theoretical maximum rate of increase predicted by Buechner (1960). Between 1979 and 2002, 266 bighorn were removed from Red Rock to establish populations in the Peloncillo, Alamo Hueco, Ladron, and Fra Cristobal Mountains, to augment these populations and the San Andres and Hatchet populations, and for experimental work.

Red Rock resembles free-ranging conditions, but confinement increases vulnerability to predation, disease, inbreeding, and harassment of ewes by rams (Elenowitz and Humphreys 1989). In 2000, additional efforts were put into fence repair and predator control, resulting in declining predation. From 1999 to spring 2003, 8 mountain lions were killed in or near the facility (NMDGF Red Rock Mountain Lion Harvest Table 2003). Despite population growth, the Red Rock population has less genetic diversity than most wild populations (Gutierrez-Espeleta et al.1998, Boyce and Ostermann 2002). An attempt was made in 1989 to reduce harassment of ewes by rams by segregating rams. High ram mortality resulted from infighting and the segregation project was terminated (Fisher and Humphreys 1990).

Red Rock has been negatively impacted over the past few years from a skewed sex ratio in favor of rams. This is partially a function of historically removing more ewes than rams during transplants to establish new populations. However, a skewed sex ratio at birth in favor of rams has also been noted. This resulted in a stable population at a lower density resulting in no ewes transplanted between 1998 and 2001. Contrary to top-down regulation of wild desert bighorn populations, predator control at Red Rock results in the population potentially being bottom-up regulated, meaning that bighorn numbers are limited by forage availability. A population

Table 2. Estimated size of 8 desert bighorn sheep populations during autumn in New Mexico 1996-2002.

Herd	1996	1997	1998	1999	2000	2001	2002
Ladron	35	30	35	30	20	26	27
Peloncillo [a]	50	45	60	55	48	30	25
Animas	15	15	10	10	6	0	0
Alamo Hueco	5	5	10	5	1	0	0
Little Hatchet	30	30	30	30	19	20	24
Big Hatchet	30	30	30	30	24	20	26
Fra Cristobal	33	44	46	53	55	66	75
San Andres	25	1	1	1	5[b]	4	60
Total	221	200	222	214	178	166	191

[a]Only includes bighorn south of I-10; 33 transplanted since 1997.

[b] 4 Sentinel rams and 1 extant ewe.

Figure 1. Occupied desert bighorn sheep ranges in 2003.

Table 3. Transplant history of occupied desert bighorn sheep areas in New Mexico.

AREA	Est. Pop. Spring 2003	DATE	SOURCE	RELEASE AREA	RAMS	EWES	LAMBS	TOTAL
Red Rock Captive herd	90	1972	Loma Prieta Mtns., Sonora , Mexico	Red Rock		5		5
			San Andres Mtns, NM	Red Rock	3	6		9
		1975	San Andres Mtns, NM	Red Rock		8		8
San Andres Mountains	73	1999	Red Rock, NM		6			6
		Nov 2001	Red Rock, NM	Range-wide	5			
		Nov 2002	Red Rock, NM	Zebra Site	18	13		31
			Kofa NWR, AZ	Zebra Site	2	18		20
Hatchet Mountains	35	Sept 1979	Red Rock, NM	Romney Canyon	2	6	4	12
		Dec 1982	Red Rock, NM	Romney Canyon	3	9	6	18
		1997	Red Rock, NM	Romney Canyon	6			6
		1999	Red Rock, NM	Granite Pass	3			3
Peloncillo Mountains	25	Jun 1981	Kofa NMW & Plomosa Mtns, AZ	Sheep Camp		10		10
			Red Rock, NM	Sheep Camp	10			10
		Sept 1981	Red Rock, NM	Sheep Camp	2			2
		Jan 1982	Kofa NWR, AZ	Gray Peak	4			4
		Nov 1982	Kofa NWR, AZ	Burro Canyon		10		10

		Jan 1991	Red Rock, NM	Burro Canyon	3			3
			Red Rock, NM	Granite Peak	3			3
		Oct 1993	Red Rock, NM	Burro Canyon	6	5		11
		1997	Red Rock, NM	P. O. Canyon	12	12		
AREA	**Est. Pop. Spring 2003**	**DATE**	**SOURCE**	**RELEASE AREA**	**RAMS**	**EWES**	**LAMBS**	**TOTAL**
		1999	Red Rock, NM	Steins, Pratt, Granite, P. O. Canyon	12			
Ladron Mountains	25	Oct 1992	Red Rock, NM	Waldrum Canyon	7	16	0	23
		Oct 1993	Red Rock, NM	Waldrum Canyon	4	4	0	8
		1997	Red Rock, NM	The Box	8	0	0	8
		1999	Red Rock, NM	The Box	3	0	0	3
Fra Cristobal Mountains		1995	Red Rock, NM	Release Canyon	13	24		37
		1999	Red Rock, NM	Red Gap	7			7

**The five Loma Prieta ewes were pregnant, contributing an additional 5 Loma Prieta bighorn to the Red Rock population

Note: In 1996, 13 bighorn were observed in the the Animas Mountains. This population was surveyed annually between 1996 and 2001, with population declines observed each year until no bighorn sheep were observed in 2001. It is hypothesized that the Animas population is now extinct.

skewed towards rams at Red Rock inhibits population growth because there are fewer ewes to reproduce. Since 1997, 83 rams and only 25 ewes have been removed from Red Rock to minimize problems associated with high ram numbers and return the sex ratio to 50-100 rams:100 ewes. Rams were radiocollared and released into wild herds to provide demographic support and to increase the ability to monitor those populations. Reproduction should not be negatively impacted in the wild by the presence of additional rams as lamb:ewe ratios in Red Rock remained high during periods with high ram:ewe ratios when the population was below carrying capacity (NMDGF Red Rock Table 2003).

In 1999, a supplemental feeding program was reinitiated in an attempt to alter the sex ratio at birth to parity based on the hypothesis that nutritional constraints were inducing the skewed sex ratio. Bighorn were supplementally fed between 1981 and 1992, and the yearling male:female ratio was 80:100 (n=110). Supplemental feeding was terminated and between 1993 and 1999, following the doubling of the size of the facility, and the yearling male:female ratio changed dramatically to 158:100 (n=155). The supplemental feeding program was reinitiated in 1999. During 2000-2002, the sex ratio shifted from 266 males:100 females, to 143 males:100 females, to 83 males:100 females, respectively (Table 4). The 2002 ratio is typical of years in which feed was supplied in the past. The feeding program reduces foraging pressure on the facility and will be continued. Until wild populations are large enough to be used as sources of transplant stock, Red Rock will continue to be the foundation of New Mexico's desert bighorn restoration program.

Peloncillo Mountains (Table 3). The Peloncillo Mountain population was established in 1981 with 10 rams transplanted from Red Rock and 10 ewes from the Kofa National Wildlife Refuge and Plomosa Mountains in Arizona. All Red Rock rams died of pneumonia following contact with Arizona bighorn (Sandoval et al. 1987). An additional 16 bighorn were released following the die-off and the Peloncillos herd increased from 16 to 50 individuals by 1991. With the addition of 17 bighorn (12 rams, 5 ewes) released in 1991 and 1993, the population subsequently increased to an estimated 60 bighorn by 1995, at which time the first hunt was held. In 1997, 24 radiocollared bighorn (12 rams, 12 ewes) were released in Post Office Canyon in an attempt to increase distribution of desert bighorn to the southern portion of bighorn sheep habitat. High mountain lion predation resulted in failure of this effort as 9 ewes were killed by mountain lions within 2 years, and only 1 ewe was alive in February 2002. In 1999, 9 radiocollared rams were released into the 3 main subpopulations (Granite Peak, Pratt Peak/Gray Peak, and Post Office Canyon). Another 3 radiocollared rams were released north of I-10 and subsequently moved into the Arizona portion of the Peloncillo Mountains. In addition, 6 extant ewes were radiocollared during a net-gun capture in November 1999. Four of these 6 ewes died within 24 months (3 mountain lion kills, 1 unknown cause) and only 1 of these ewes was known to be alive in 2002 (1 radiocollar accidentally dropped) (NMDGF Population Tables 2003). Currently the population estimate is 25, with approximately 7 ewes remaining (Goldstein and Rominger 2003). In total, 97 bighorn have been transplanted to the Peloncillos during 8 transplant efforts (37 ewes, 52 rams, and 8 lambs) [see *Red Rock*].

During the last 20 years, Peloncillo bighorn have intermingled with Arizona bighorn in the Arizona-New Mexico border area and are known to have visited the Hatchet and Animas

Table 4. Sex-ratio of recruited yearlings in Red Rock during years of providing supplemental feed for bighorn, and during years when no supplemental feed was provided.

Years	Males	Females	Sex Ratio (males:100 females)
1974-1978 (no feed provided)	11	9	122:100
1981-1992 (feed provided)	49	61	80:100
1993-1999 (no feed provided)	95	60	158:100
2000 (feed provided)	8	3	266:100
2001 (feed provided)	10	7	143:100
2002 (feed provided)	10	12	83:100
Total recruitment	155	130	119:100

Mountains. However, none of the 39 bighorn captured or released south of Interstate Highway 10 in the Peloncillo Mountains since 1997 has been observed outside the New Mexico portion of the Peloncillo Mountains. Because the Animas Mountains separate the Peloncillo Mountains from the Hatchet and Alamo Hueco Mountains, they are an important link between mountains in this bootheel region [see *Animas Mountains*].

If bighorn are present at a release area prior to a transplant, transplanted bighorn may learn habitat use patterns from resident bighorn, resulting in lower mortality rates than if new bighorn had to learn everything without mentors. Therefore, reintroductions have a greater likelihood of success and a better chance of lower mortality rates in the year or 2 post-release when bighorn are already present. Mountain lion predation has been the documented cause of mortality for approximately 85% of all known-cause non-hunter radiocollared adult bighorn mortalities in the Peloncillos. From October 2001 through May 2003, contractors have removed 7 mountain lions from this range (NMDGF Harvest Files 2003). The harvest levels increased each year, but it is too early to determine the efficacy of the program. Augmentation of the Peloncillo population, as necessary to prevent extirpation, is viewed by NMDGF as a high-priority action, and given the current level of mountain lion removal an augmentation is proposed for 2003.

Hatchet Mountains (Table 3). Indigenous Big Hatchet Mountain bighorn numbers declined from an estimated 125 bighorn in the early 1950's to less than 15 in 1978 due to severe drought, competition for reduced forage by cattle and deer, and predation (Gross 1960, Lenarz 1978, Watts 1979). Supplemental transplants of 12 Red Rock bighorn (6 ewes, 2 rams, 4 lambs) in 1979 (Bavin 1980) and 18 bighorn (11 ewes, 3 rams, 4 lambs) in 1982 increased and stabilized the remnant herd. By 1987, an estimated 80 bighorn were in the Big Hatchets. During this time a self-starting resident herd became established in the Little Hatchet Mountains (Elenowitz and Humphreys 1987, 1989). Recent declines in this population have primarily been due to mountain lion predation (NMDGF Mortality Tables 2003). The Hatchet herd has decreased substantially since 1995, despite transplanting 9 rams from Red Rock [see *Red Rock*].

This herd is distributed in 2 distinct subpopulations about 7 miles apart in the southern Little Hatchet and southern Big Hatchet Mountains. None of the 17 bighorn radiocollared in 1997 and 1999 has been documented to move between these 2 ranges. However, a ram released in the Little Hatchet Mountains in 1999 was killed by a mountain lion in the flats between the Little Hatchet and Big Hatchet Mountains during an attempted inter-mountain movement. In 1997, 6 radiocollared rams were released into the Big Hatchet Mountains from Red Rock. In 1999, 3 radiocollared rams were released into the Little Hatchet Mountains and 8 extant ewes were radiocollared (3 in the Big Hatchet Mountains and 5 in the Little Hatchet Mountains) (NMDGF Population Tables 2003). There have been 12 known mortalities including 9 mountain lion kills, 1 poaching, 1 capture related mortality, and 1 natural death. The population estimate in 2003 was 35 and just 1 ewe is known to be in the Big Hatchet Mountains (Rominger and Goldstein 2003). Lack of fire [see *Fire Frequency*] is hypothesized to be related to high predation levels in this herd because of the increase in ambush cover. Population levels have declined such that a future augmentation will almost certainly be required if the Hatchet Mountains population is to be maintained.

San Andres Mountains. When the SANWR was created in 1941, the desert bighorn population was estimated to be 31 individuals. This increased to an estimated 140 desert bighorn sheep by 1950, but declined to 70 bighorn by 1955 due to severe drought and competition for reduced forage by cattle and deer. The population slowly increased through the l960's and stabilized at approximately 200 bighorn during the mid-1970's (Sandoval l979a). In l978, psoroptic mites (*Psoroptes* spp.) were detected on 5 hunter-killed rams (Lange et al. 1980). By September l979, the population had declined to an estimated 75 bighorn (Sandoval l980).

After on-range attempts to treat bighorn with coumaphos dust bags proved unsuccessful, NMDGF and SANWR captured 49 of approximately 75 bighorn in 1979 (Hawkes l980). They were dipped in a toxaphene solution, released into a 6 acre holding facility constructed near the base of the mountain, and dipped again. Thirty-five bighorn survived the treatment. Seven rams were brought to New Mexico State University for scabies (*Psoroptes spp*.) mite cross transmission trials that failed to establish the San Andres mite on mule deer, aoudad *(Ammotragus lervia)*, and oryx (*Oryx gazella*), and were established with difficulty on domestic cattle, and domestic sheep (Kinzer et al. 1983, Wright et al. 1981). In contrast, Red Rock bighorn were highly susceptible to the mite; suggesting that the San Andres mite was host specific to desert bighorn and biologically distinct from mites that may infect other ungulate species found in desert bighorn range. The remaining 28 bighorn were brought to Red Rock where they remained for 13 months (Sandoval l980). Twelve of the San Andres bighorn survived a suspected epizootic of blue tongue at Red Rock and were returned to the San Andres Mountains in January 1981.

Between l980-83, 62 bighorn were treated with the parasiticide ivermectin via hand held injection and aerial delivery of ballistic implants. These treatments reduced the proportion of captured animals with clinical infections from 96% in l979 to 11% in 1984. In 1989, bighorn were captured and treated with a sustained release ivermectin formulation that would confer immunity against scabies for 90 days. Scabies could not be eradicated because some mite infested animals always eluded capture and reinfected treated animals (Sandoval 1980, 1985). In 1989, scabies mites were discovered on mule deer in the San Andres Mountains. A study was conducted to investigate host specificity of deer and bighorn mites. The complex nature of comparing genetics resulted in the study being inconclusive (Ramey 1996). How scabies were transmitted to bighorn in the San Andres remains unclear.

Between 1980 and 1984, 41 mountain lions were removed from bighorn sheep range in the San Andres in an attempt to decrease mountain lion predation on bighorn (Elenowitz and Humphreys 1987). Although annual mountain lion mortality rates on bighorn sheep dropped from 0.349 to 0.048, the program was discontinued. Between 1982 and 1994 bighorn numbers ranged between 25 and 35 animals (NMDGF Survey Records). In 1995-96, a severe drought contributed to mule deer population decline. This decline was exacerbated by high mountain lion predation (Logan et al. 1996). By 1997 there was only 1 remaining ewe in the San Andres Mountains (Rominger and Weisenberger 2000). A minimum of 67% of the radiocollared bighorn sheep mortalities was due to mountain lion predation (Rominger and Weisenberger 2000). In 1999, the *Document for the Recovery of Desert Bighorn Sheep in the San Andres Mountains* was approved by NMDGF,

SANWR and the White Sands Missile Range (WSMR) (NMDGF 1999). As a result, a 2-year sentinel ram study was initiated in autumn 1999 with 2 primary goals: (1) to determine that bighorn and their habitat were free of scabies; and (2) to learn if there were additional bighorn in the San Andres. In 5 recaptures during the sentinel ram project, neither remaining ewe nor any of the 6 sentinel rams released from Red Rock in 1999 tested positive for scabies. No additional bighorn were located. Therefore, as of November 2001, the San Andres herd was considered scabies-free.

As the largest and most contiguous desert bighorn range in New Mexico, the San Andres Mountains are considered critical to desert bighorn recovery. In cooperation with the Arizona Department of Game and Fish (AZGF), the Kofa National Wildlife Refuge, the Arizona Desert Bighorn Sheep Society, the Foundation for North American Wild Sheep (FNAWS), SANWR, and WSMR, NMDGF is planning to receive up to 60 desert bighorn sheep from 2000-2007 from AZGF. In return, AZGF will receive an approximately equal number of Rocky Mountain bighorn sheep from NMDGF (NMDGF 2002). In November 2002, AZGF sent 18 ewes and 2 rams to NMDGF. These desert bighorn plus 13 ewes and 18 rams from Red Rock were placed on SANWR. In combination with the 9 bighorn already present, these 60 bighorn were the largest desert bighorn transplant in New Mexico to date (Table 3). An aggressive mountain lion control program [see *Predators*], in combination with daily monitoring of the new population, should allow for expansion of this herd (USFWS 2002). If restored, this herd could serve as a transplant source for other populations when it reaches a large, stable size. Transplants out of the population could occur as long as a minimum of 50 ewes and 100 animals total remain after the transplant has occurred (NMDGF 2002).

Ladron Mountains (Table 3). The Ladron Mountain population was established in 1992 with 23 bighorn (16 ewes and 7 rams) transplanted from Red Rock (Knadle and Thompson 1993), and was supplemented the following year with 8 bighorn (4 ewes, 4 rams) from Red Rock. After initial high losses of 6 bighorn in the first year to poaching, mountain lion predation, and an accidental fall, the estimated population increased slightly to 35 bighorn (NMDGF Mortality Tables 2003, Knadle 1993). Despite an augmentation of a total of 11 radiocollared rams in 1997 and 1999, this population declined to approximately 25 individuals by 2003. Mountain lion predation has been the most common cause of mortality (15 confirmed mountain lion kills of 21 total radiocollared mortalities recorded, the other 6 were from unknown causes, some of which were likely mountain lion kills) and between 1992 and 2000 the annual cause-specific mortality rate due to mountain lion predation was 11% (Rominger et al. submitted). Bighorn use most lower-elevation habitat in the Ladron Mountains and the Rio Salado drainage between Riley, NM and the Silver Creek area on the Sevilleta National Wildlife Refuge. Bighorn have also been observed on Mesa Sarca and in 1996, 15 bighorn moved nearly 60 km south to "M" Mountain just west of Socorro, NM. Although this group had no marked bighorn they apparently returned to the Sierra Ladron based on the number of observed bighorn in subsequent surveys. In 2000, 5 bighorn were captured and radiocollared in a net-gun operation designed to assist monitoring of this population during a Masters project at New Mexico State University (Arana 2001). From 1997 through May 2003, 14 mountain lions were removed from the Ladrons; 11 of them were removed between December 2001 and May 2003. The effectiveness of the mountain lion control will be evaluated and used to guide future management of this herd.

Fra Cristobal Mountains (Table 3). In November 1995, 37 bighorn sheep (13 rams and 24 ewes) were transplanted to the Fra Cristobal Mountains on the Armendaris Ranch, owned by New Mexico Ranch Properties Incorporated (NMRPI), to establish a bighorn population (Krausman et al. 2001). In 1997, 7 radiocollared rams were released from Red Rock, but 6 of these rams were killed by mountain lions within 18 months. Despite documentation of substantial mountain lion predation on this population (n=29), it increased to an estimated 75 individuals in 2002 (NMDGF Mountain Lion Harvest Files 2003, Parsons 2002). However, it took 7 years for the number of ewes to increase from 24 to 34 ewes. In spring 2003, only 58 bighorn were observed in the Fra Cristobals Mountains, but the loss is attributable mainly to 9 yearling females and 17 rams. Whether these individuals are dead or have emigrated is unknown. Turner Endangered Species Fund (TESF) and NMDGF have employed a wildlife biologist to monitor these bighorn sheep since 1995. Two graduate projects have been conducted on this population (Bangs 2002, Parsons in prep.). A lamb mortality study was conducted in 2001 and 2002, and 14 lambs were radiocollared. Cause of death was determined for 11 lambs. Causes included mountain lion predation (n=5), golden eagle predation (n=3), disease (n=1), accident (n=1), and an unknown predator (n=1) (Parsons 2001 and 2002). With the end of the graduate student research, a mountain lion trapper/bighorn sheep monitor was employed by TESF to monitor bighorn sheep, radiocollar additional mountain lions, track their movement patterns, and to identify individuals that prey on bighorn sheep.

❖ Unoccupied Historic Desert Bighorn Range

Alamo Hueco Mountains (Table 5, Figure 2). The Alamo Hueco Mountain population was reestablished in 1986 with 21 bighorn (10 rams, 10 ewes, 1 lamb) transplanted from Red Rock (Axtell 1988). From 1986-1996, this population was never documented to be more than 30 individuals (NMDGF Survey Records). However, since 1996 the greatest number of bighorn observed in the Alamo Huecos has been 7 (Rominger and Goldstein 2001). A single ram was observed in 2000 and no lambs have been observed since 1998. Three radiocollared rams were released in the Alamo Huecos from Red Rock in 1999 [see *Red Rock*]. One radiocollar failed almost immediately and the other 2 rams are generally monitored in the Big Hatchet Mountains, including during the rut, suggesting no ewes remain in the Alamo Hueco population (NMDGF Population Tables 2003). It is therefore hypothesized that the Alamo Hueco population is extirpated and bighorn observed in the Alamo Hueco Mountains are transients from the Big Hatchet population.

Animas Mountains (Table 5, Figure 2). During the 1996 helicopter survey, 13 bighorn sheep hypothesized to be from the Granite Peak subpopulation in the Peloncillos were observed in the Animas Mountains, making this the only documented case of colonization in New Mexico (excluding movement into the Little Hatchet Mountains) (Rominger 1996). This population was surveyed annually between 1996 and 2001, with population declines observed each year. In 1999, 2 ewes were radiocollared but within 12 months both ewes were killed by mountain lions, and no bighorn sheep were observed in 2001 or 2002 (NMDGF Population Tables 2003). It is hypothesized that the Animas population is now extirpated.

Table 5. Potential desert bighorn sheep transplant areas in New Mexico with no resident bighorn populations.

AREA	HABITAT (km^2)	POTENTIAL NUMBER[1]	JURISDICTION[2]	ISSUES
Alamo Hueco Mountains[6]	172	80-170	BLM (54%); Private (43%); State (3%)	High lion predation suspected in recent extinction. Principal access restricted by privat land.
Animas Mountains[3]	127	60-120	Private-Gray Ranch (60%) BLM (25%), State (15%)	High lion predation resulted in recent extinctio
San Andres Mountains, north of the SANWR[3]	650	325-650	US Army, WSMR, FWS	Bighorn released in 2002 on SANWR; Would require mountain lion mitigation for second release north of SANWR.
Caballo Mountains[3]	70	100-150	BLM (86%), State (9%), Private 5%	Previous public opposition would need to be addressed.
Organ Mountains[3]	140	70-140	US Army, Ft Bliss (73%) BLM (22%), Private & State (5%)	Bighorn sheep released in 2002 may move intc the Organ Mountains.
Oscura Mountains[3]	41	20-40	WSMR	Bighorn sheep release into a northern San Andres location may cross into the Oscuras.
Magdalena Mountains[3]	57	30-60	BLM (70%); Private (30%)	None. Waters and necessary paperwork completed (Heft 1995).
El Malpais[4]	163	80-160	NPS (100%)	Paddock release may be needed to habituate bighorn because of different physiography. Domestic sheep and goats on nearby reservations.

San Mateo Mountains[3]	54	25-50	Cibola NF	None.
Black Range[5]	44	20-40	Private-Ladder Ranch, Gila NF	7/8 cross Persian wild goats on Ladder Ranch deter transplants.
Carlisle Canyon[3]	65	35-65	BLM 47%; Private 37%; State 16%	None.
AREA	**HABITAT (km^2)**	**POTENTIAL NUMBER[1]**	**JURISDICTION[2]**	**ISSUES**
Sacramento Mountains[6]	70	35-70	Lincoln NF (59%); U.S. Army (21%); BLM (10%); Private (9%)	Aoudads, feral goats, and domestic sheep deter transplants.
Guadalupe Mountains[6]	78	40-80	Lincoln NF (58%); NPS (28%); BLM (9%),;Private (5%); State (3%)	Aoudads, domestic sheep, and feral goats preclude transplants.

[1]Potential numbers were derived based on a minimum of 0.5 bighorn/km^2 as reported in Singer and Gudorf (1999), ranging to a maximum of 1.0 bighorn/km^2 which is a conservative number based on field observations in New Mexico. [2]FWS=Fish and Wildlife Service; WSMR=White Sands Missile Range; BLM=Bureau of Land Management; NF= U. S. Forest Service
[3]Dunn 1994, [4]Dunn 1993a, [5]Dunn 1993b, [6]Sandoval 1979a

Figure 2. Unoccupied desert bighorn sheep ranges in 2003.

Caballo Mountains (Table 5, Figure 2). This range contains high quality habitat for a bighorn sheep herd (Dunn 1994). Bighorn hypothesized to be from the Fra Cristobal population have been documented in the Caballo Mountains. A 1992 proposal to transplant bighorn sheep to the Caballo Mountains was unsuccessful because of issues related to public perception and human activity. These issues need to be resolved before transplanting bighorn to this range. A population in the Caballo Mountains would be part of a metapopulation with the Fra Cristobal population.

San Mateo Mountains (Table 5, Figure 2). There is a moderate amount of good quality habitat, but not a lot of escape terrain (Dunn 1994). There are no impediments to reintroduction of bighorn though the area may not be able to support a very large herd and a metapopulation link with the population in the Sierra Ladron is unlikely. However, if bighorn were established in the Magdalena Mountains and/or the Black Range a metapopulation would be more likely.

Malpais (Table 5, Figure 2). The presence of poor quality vegetation, and small amount of habitat with good visibility that is near escape terrain makes this area much less suitable for a bighorn transplant than other unoccupied territories. The very different physiography of a lava-bed habitat might require a paddock release. The proximity to domestic sheep and goats is cause for concern and would currently preclude a bighorn release in this area.

Magdalena Mountains (Table 5, Figure 2). The Devil's Backbone has good quality habitat and has previously been considered for a bighorn sheep transplant. The grassy rolling terrain would be different than rockier ranges with less grass currently occupied by desert bighorn. Distance to nearest herds would also be greater than for most populations within a viable metapopulation.

Guadalupe Mountains (Table 5, Figure 2). While this range is comprised of good quality bighorn sheep habitat, and had native bighorn until the 1940's, the presence of domestic and Barbary sheep currently preclude reintroduction of desert bighorn sheep [see *Domestic sheep and goats* and *Exotic ungulates*] (Sandoval 1979a). Private landowners once grazed thousands of domestic sheep. With the decreased value of wool, this number has dramatically declined, however, many landowners retain domestics and numbers could increase should the wool market rebound. There are an estimated 400-770 Barbary sheep in the Guadalupe Mountains with even greater numbers north of the range. Until domestic sheep are eliminated or double fenced, and Barbary sheep are eliminated or substantially reduced, this mountain range will not be viable habitat.

Sacramento Mountains (Table 5, Figure 2). There have been no historic reports of bighorn on this mountain, however there are reports of their presence starting in the 1930s (Sandoval 1979a). Bighorn habitat is limited but the range could support a small bighorn population. Presence of domestic sheep, Barbary sheep, and feral goats currently preclude transplants to this area [see *Guadalupe Mountains*] (Sandoval 1979a).

Florida Mountains (Table 5, Figure 2). This mountain range has a large amount of optimal bighorn sheep habitat. However, there is strong overlap in diet composition and habitat use between desert bighorn and ibex *(Capra aegagrus)*, an exotic ungulate living in this range [see

Exotic Ungulates]. The presence of ibex precludes establishment of a bighorn population in these mountains.

Black Range (Table 5, Figure 2). This mountain range would be suitable habitat to support a small herd of desert bighorn sheep and may potentially contribute to a metapopulation comprised of herds in the San Mateo, Magdalena, and Sierra Ladron Mountains. Long distances between these mountain ranges are suboptimal for a metapopulation.

❖ Habitat Assessment

Bighorn habitat evaluations by Sandoval (1979a, 1982) and Dunn (1993, 1994) identified suitable habitat and limiting factors in potential transplant sites (Table 5). Past transplants were based on these evaluations and they will continue to be used to identify problems and rank transplant sites. Dunn's evaluation was based on 7 components including escape terrain, metapopulation potential, habitat contiguity, primary water sources, critical habitat, range impact, and human impact. Study areas were eliminated from consideration as transplant sites if they had less than 50 km^2 of escape terrain or had a minimum of 35 km of flat terrain separating them from the next closest potential or occupied range. Using a density range of 0.5 – 1.0 bighorn/km^2, we estimated potential carrying capacity in each range (Table 5). These densities are extremely conservative. Red Rock had a density of 19 bighorn/km^2 when they were not fed between 1993 and 1999 (Rominger et al. submitted). High density populations in the Mojave desert in Nevada have been documented to be approximately 2 bighorn/ km^2 (McQuivey 1978). The Mojave desert receives less precipitation than the Chihuahuan desert resulting in a lower plant biomass. Therefore, Chihuahuan desert habitats may be able to support higher densities of desert bighorn.

Conditions may arise to warrant adding additional ranges to this list. Occupied sites listed in Table 6 may be supplemented with bighorn as required. The San Francisco River and Turkey Creek drainages are historic desert bighorn sites now occupied by Rocky Mountain bighorn (*O. c. canadensis*). Habitat in these areas, as well as in the Manzanos, have characteristics of both Rocky Mountain and desert bighorn habitat, and it may be that bighorn in this area fell in the middle of a cline between Rocky Mountain and desert bighorn. It is possible that a genotype that is a cross between Rocky Mountain and desert bighorn may give these animals their greatest chance for survival.

❖ Supply

Statewide, based on conservative density estimates, there is the potential for 1,082 - 2,113 individuals within six populations and/or metapopulations (Table 6). Numerous private landowners and agencies involved in managing these lands necessitate excellent communication and early involvement of all parties that may be affected by bighorn management. The Red Rock captive population serves as source stock for repopulating New Mexico with desert bighorn sheep. Transplants from Red Rock to the Hatchet, Alamo Hueco, Peloncillo, Ladron, San Andres, and Fra Cristobal Mountains occurred between 1979-2002. A total of 266 desert

Table 6. Metapopulation objective for desert bighorn sheep in New Mexico.

Metapopulations	Spring 2003 Pop. Estimate	Potential Pop. Estimate	Potential Metapop-ulation Estimate
Peloncillo Mountains	25	100-200	274-547
Hatchet Mountains	25	80-160	
Alamo Hueco Mountains	0	30-60	
Animas Mountains	0	64-127	
Ladron Mountains	25	25-50	102-205
Magdalena Mountains	0	28-57	
San Mateo Mountains	0	27-54	
Black Range	0	22-44	
Fra Cristobal Mountains	58	100-150	135-220
Caballo Mountains	0	35-70	
El Malapais	0	82-163	82-163
San Andres Mountains	73	325-650	417-830
Organ Mountains	0	70-140	
Oscura Mountains	0	22-41	
Guadalupe Mountains	0	37-78	72-148
Sacramento Mountains	0	35-70	
Total Statewide Number			1,082 - 2,113
Total Number of Metapopulations			6

bighorn have been released into the wild from Red Rock. An additional 10 ewes from Arizona were released in the Peloncillo Mountains in 1981-1982, and 20 bighorn (18 ewes and 2 rams) were released in the San Andres Mountains from Arizona (Sandoval et al. 1987, NMDGF Transplant Records 2003).

In spring 2003, an estimated 213 desert bighorn occurred in the wild, with an additional 91 in Red Rock. As recently as 2000, wild bighorn occurred in 7 populations, however, since 1996 the Alamo Huecos, Animas, and San Andres populations have declined to less than 5 individuals or gone extinct (the San Andres have since been restocked) (Rominger and Goldstein 2002). These numbers demonstrated a declining population trend from 1996 through 2001. However, from 2001-2002 statewide populations were stable for the first time in four years, with the Fra Cristobal population increasing from 66 to 75 individuals. The addition of the new San Andres population during November 2002 increased state-wide numbers. Between 2002 and 2003, as a result of an apparent decline in the Fra Cristobals and the Big Hatchets, the statewide population decreased slightly. The remaining herds were stable (Peloncillos and Ladrons) or increasing (Little Hatchets and San Andres). If a population grows to greater than 100 individuals with a minimum of 50 ewes NMDGF will consider using the wild population for transplant stock.

VORTEX modeling of New Mexico desert bighorn sheep populations was done during a Population Viability and Habitat Analysis workshop specifically on New Mexico desert bighorn sheep (Fisher et al. 1999). All extant herds were predicted to go extinct within 65 years based on conditions present during 1999.

❖ Demand

The long history of hunting desert bighorn in New Mexico is one indicator of the public's interest in having this animal in the state. Prior to 1979, desert bighorn hunting was opened for brief periods. In 1954 and 1955, 17 rams were harvested in the Hatchet Mountains before the population declined in 1956 due to drought and competition for forage. Between 1968 and 1978, 57 rams were harvested in the San Andres Mountains before the scabies epizootic caused a sharp decline in the herd (NMDGF Harvest Files). In 1995, after a closure of 16 years, desert bighorn hunting was opened in the Peloncillo Mountains for the first time since the reestablishment of the herd. The average number of people to apply for the single public draw desert ram tag available each year was 594.

In 1989 the New Mexico Legislature authorized the auction of one Rocky Mountain bighorn sheep hunting permit to the highest bidder, and in 1995 this permit was expanded to provide the hunter the option of hunting a Rocky Mountain or desert bighorn ram. This auction is conducted through the National Chapter FNAWS. Proceeds are used exclusively for bighorn sheep management programs. NMDGF receives 75% reimbursement from Federal Aid in Wildlife Restoration (derived from federal excise taxes on sporting arms and ammunition) for the majority of its programs. For the first 5 years, bid price averaged $59,200 for a Rocky Mountain bighorn hunt. In 1995, with the addition of the desert ram option, the winning bid was $123,000. Since then, winning bids have ranged from $75,000 to $157,500, with an average of $101,222. As of 2003, 5 of 9 auction hunters have chosen to hunt desert bighorn, with the 5 tags generating

a total of $461,000. The prices received for these auction permits, combined with the high number of applicants for the annual public draw, indicate the high value placed on hunting bighorn. The Peloncillo population is the only herd in New Mexico where hunting is legal, but if population declines continue then future hunts will have to be cancelled. Revenues generated from auction tag sales go directly to the bighorn budget, therefore canceling the Peloncillos hunt may greatly reduce the scope of bighorn restoration NMDGF can accomplish.

In 2000 the legislature created a raffle license for the opportunity to hunt one Rocky Mountain or desert bighorn ram. The raffle is conducted through the New Mexico chapter of FNAWS, and has raised a total of $152,840 from 2000-2002. One of 3 raffle hunters has hunted a desert bighorn sheep. From 1995-2003, 15 desert bighorn tags have been issued (9 public draw, 5 auction, and 1 raffle).

Currently, 4 landowners have signed an agreement with NMDGF that allows hunter access through or onto private land occupied by bighorn sheep. Regulations allow an individual to hold only 1 public draw desert bighorn sheep permit in a lifetime, stipulate a bag limit of 1 bighorn ram, and require the skull be sealed, measured, and photographed by NMDGF. In addition to hunting, many publics enjoy having desert bighorn present in the ecosystem so that they may view these animals, and derive a personal satisfaction by knowing they are there.

❖ Economic Impact

NMDGF is the primary entity funding desert bighorn sheep management, although federal agencies and cooperators provide significant contributions to desert bighorn conservation. These costs may include, but are not limited to, expenses associated with bighorn transplants, annual helicopter surveys, monitoring, university graduate projects, habitat manipulations, and measures to reduce disease transmission potential from livestock to bighorn. Bighorn restoration may generate revenue for local economies (USFWS 2003). Transplants are large-scale events that involve many people who will be supporting the local economy by patronizing hotels, gas stations, restaurants, grocery stores, etc. during transplant operations. Hunters are likely to hire local guides, stay in hotels, and eat in restaurants close to bighorn range. Persons who view desert bighorn sheep also contribute to local economies in similar ways as hunters. It is unlikely that there will be any negative economic impacts to local economies from desert bighorn recovery activities. A more extensive economic analysis may be conducted for individual projects if deemed necessary by the involved publics.

❖ Special Considerations

Desert bighorn sheep in New Mexico face a variety of potential threats. In order to achieve the state's management objectives for desert bighorn sheep, a comprehensive, science-based assessment of factors limiting each population of desert bighorn sheep must be conducted. The factors described below represent potential impacts that must be considered, and some of these factors may have to be mitigated in order to achieve self-sustaining populations of bighorn sheep. The decision of whether to implement management actions to address these factors will have to be tailored for individual bighorn sheep populations and habitat. In addition, an

evaluation of the following factors can help determine the feasibility and likelihood of success in re-establishing desert bighorn within currently unoccupied habitats.

Fire Frequency. Decreased fire frequency has lead to increased woody vegetation density in most bighorn sheep ranges in the west (Wakelyn 1987). While fire suppression policies of land management agencies over the past 80 years have contributed to lack of fire, livestock overgrazing is the primary cause of reducing fine fuels that enable a fire to carry. Increased density, size, and percent canopy cover of pinyon pines (*Pinus edulis*), junipers (*Juniperus spp*), and oaks (*Quercus spp*.) have decreased visibility for bighorn and provide additional cover for predators (Wakelyn 1987, Huddleston-Lorton 2000). Prescribed burns and a natural fire regime are an integral component of habitat and bighorn restoration. Bighorn need good visibility in order to perceive predators in time to escape from them (Risenhoover et al. 1988). Prescribed burns can be used to open these areas to increase the amount of suitable bighorn range (Wright and Bailey 1982, Hobbs and Spowart 1984, Krausman et. al 1996, Smith et al. 1999) and to potentially decrease the frequency of mountain lion kills. Several prescribed burns and wildfires have occurred in desert bighorn range in the Hatchet, Ladron, and San Andres Mountains in the past 10 years (Table 7). The majority of these fires were not very successful because weather conditions were often either too cool or too humid to successfully carry a fire. However, more than 34,000 acres have been successfully treated on the SANWR in past prescribed burns intended to improve desert bighorn sheep habitat conditions. In addition, burns in the Big Hatchet and Ladron Mountains during 2003 burned 2,600 and 1,200 acres, respectively. Prescribed burns help restore habitat conditions to those that existed before European settlement altered the natural fire regime.

Planning and implementing a prescribed burn is a large task that requires cooperation between land management agencies and private landowners in the areas to be burned. Moving cattle off the proposed burn area prior to and after the burn, and hand manipulating woody vegetation are a few of the management tools that need to be implemented. The substantial amount of work that must be done before a burn can occur necessitates careful long term planning with all parties involved. A fire regime with increased frequency of natural or prescribed fire should benefit wildlife that use habitats indicative of early desert successional stages, while adversely impacting wildlife utilizing climax desert community habitats if required habitat is lost. However, there is a difference in short term versus long term effects as the ecosystem will change over time after fire impacts an area.

Predators. Desert bighorn are preyed on by mountain lions, coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and golden eagles (*Aquila chrysaetos*) (NMDGF Mortality Tables). Gray wolves (*Canis lupus*) have been re-established within the Blue Range Recovery Area of Arizona/New Mexico. Although the New Mexico portion of this recovery area is limited to being within the exterior boundaries of the Apache and Gila National Forests, wolves have the potential to leave the area and colonize other ranges. If wolves move, or are introduced to the San Andres Mountains, oryx may become a prey species for wolves, making wolves a subsidized predator in that ecosystem. This would introduce a potential wolf predation threat to bighorn sheep. In large, free-ranging populations, predation is not generally considered a limiting factor. However, predation can be a significant mortality factor in fenced, recently reintroduced, or small

7. Fire history in desert bighorn habitat in New Mexico 1992-2003.

Date	Range	Acres	Comments
1992	Peloncillos	?	Owl Canyon Fire—wild-fire
6/94	Big Hatchets	800	Wildfire burn on the top of Big Hatchet Peak; created a large area of p-j skeletons. Occurred during the longest period of over 100 degree consecutive days on record in southern NM. Highs were over 110 on several days that June. Fires burned actively through the night that June
6/94	Peloncillos	250	Weatherby Fire; between Pratt and Eagle Nest,
6/99	Ladron	?	Dageer Ridge; high humidity made it ineffective
6/99	San Andres Black Brushy	1,700	USFWS control burn; high humidity resulted in less effective burn than desired
4/99?	SF River	350	USFS control burn; on Sundial Mt. Very cool morning and not very effective
6/00?	Los Pinos	?	Wildfire burned from east-west across central portion of the Los Pinos Mountains
6/01	San Andres	16,500	USFWS control burn on Bennett/Black Brushy; very good burn with excellent conditions; springs flowed w/in days
6/03	San Andres	16,000	San. Andres Mountains, very good burn with excellent conditions
6/03	Ladrons	1,200	South-facing areas
6/03	Big Hatchets	2,600	In south half of range
Proposed Fires			
	Peloncillos		Gray Peak—south—plan not completed
	Big Hatchets	20,000	Proposed in north half of range—plan not completed

populations, as is the case in New Mexico (Wehausen 1992, Rominger and Weisenberger 2000, Hayes et al. 2000). Additionally, populations that habitually use habitat far from escape terrain or in heavy vegetative cover are more vulnerable to predation (McQuivey 1978).

Mountain Lions (Tables 8, 9, and 10). Mountain lions are the principal predator on desert bighorn in New Mexico. Between 1992 and May 2003, 86 of 120 non-hunter killed adult desert bighorn sheep were documented to have been killed by mountain lions. The remaining 34 individuals died due to other known causes, or due to unknown causes of which many are suspected mountain lion kills. Because only a portion of the statewide desert bighorn sheep population was radiocollared during this period, this is hypothesized to be a fraction of the total mortality. Most kills were found by use of radiocollars, however some cases were found incidentally or by following radiocollared mountain lions. Approximately 85% of all known-cause non-hunter related mortalities on radiocollared individuals in wild desert bighorn herds in New Mexico are due to mountain lion predation. Predation by mountain lions was the primary proximate cause of the biological extinction of the remnant San Andres population following a significant population reduction in the late 1970's due to a psoroptic mite infestation [see *San Andres*] (Rominger and Weisenberger 2000). Predation by mountain lions is considered the principal limiting factor in all desert bighorn sheep populations in New Mexico, whether they are born in the wild or introduced from Red Rock (Tables 8 and 9). Extinction probabilities were calculated for New Mexico populations using VORTEX modeling (Fisher et al. 1999). All extant populations had a 100% probability of extinction within 65 years given current demographic parameters and 5% additive mortality rate due to mountain lion predation. Using MICROMORT, the Ladron population was calculated as having an 11% additive annual mortality rate due to mountain lion predation (Rominger et al. submitted). While this statistic has not been calculated for other populations, it is likely the rate is similar based on the similar percentage of mountain lion kills in other populations.

Predator control is recommended as a wildlife management tool to protect rare or endangered species (Hecht and Nickerson 1999). Mountain lion removal has been successful because of the animal's social structure, which is quite different from mesocarnivores such as coyotes where removal has not always been effective. Mountain lions are solitary animals that are slow to recolonize vacated areas (Logan et al. 1996). Any individual mountain lion may prey upon desert bighorn. In contrast, coyotes are pack animals and it is necessary to remove the alpha male and female to slow reproduction and predation (Blejwas et al. 2002). Mountain lions are top carnivores with lower densities relative to other carnivores. Therefore it should be possible to reduce population numbers sufficiently to reduce predation rates. Coyotes can occur at higher densities, therefore it is more difficult to remove enough animals to be effective, or to selectively remove breeding pairs. Predation by mountain lions on mesocarnivores (coyotes, bobcats, foxes) has been documented but is not common, nor do they behaviorally exclude other carnivores from usable habitat. Therefore there is no support for a mesocarnivore release following mountain lion control as hypothesized in coyote/fox interactions.

Until 1985, NMDGF controlled mountain lions to benefit desert bighorn sheep populations, but subsequently mountain lion control was only permitted in Red Rock. In the San Andres Mountains, 41 mountain lions were removed from late 1980 to early 1984 to benefit desert

Table 8. Cause of mortality for 80 radiocollared desert bighorn sheep transplanted from Red Rock 1992 – May 2003.

HERD (n=total)	LION KILL	UNK.	ACCIDENT	POACH	OTHER PRED.	LEGAL KILL*	COLLECTED
Fra Cristobals n=44	22	2	2		1		1
Ladrons n=35	14	6	2	2			
Peloncillos n=38	11				1	5	
Little Hatchets n=3	2						
Alamo Huecos n=3	0						
Big Hatchets n=6	2	1					
San Andres n=42	5	5					
TOTAL n=171	56	14	4	2	2	5	1

None of the legally killed rams was collared, inducing a bias, i.e., lion kill is 80% of known cause mortality w/out legal kill included.

Table 9. Cause of mortality for 15 of 42 wild (non-Red Rock) desert bighorn sheep captured and radiocollared; November 1999, May 2000, and November 2002 (Kofa NWR).

Herd	LION KILL	UNK.	ACCIDENT	POACH	UNK. PRED.	LEGAL KILL	COLLECTED
Fra Cristobals n=4	**1**	**1**					
Ladrons n=4	**2**						
Peloncillos n=4	**3**	**1**					
Little Hatchets n=5	**1**			**1***			
Big Hatchets n=3	**2**						
Animas n=2	**2**						
San Andres n=20	**1**						
Total	**12**	**2**		**1**			

*Scavenged by lion; (86% lion kill of total).

Table 10. Lions harvested in 4 bighorn sheep ranges from October 1999-May 2003.

	Peloncillos		**Hatchets**		**Sierra Ladron**		**San Andres**		
Year	Contract	Sport Harvest	Contract	Sport Harvest	Contract	Sport Harvest	Contract	Sport Harvest	Totals
1999-2000	0	0	0	1	0	1	0	1	3
2000-2001	0	1	0	0	1	0	0	6a	8
2001-2002	4	3a	1	1	4	0	0	0	13
2002-2003b	4	2	2	1	7b	1	16	0	33
Totals	8	6	3	3	12	2	16	7	57

a) includes 1 road-kill
b) includes 1 NMDGF livestock depredation take

bighorn (Elenowitz and Humphreys 1987). During this time, average annual bighorn mortality rates decreased from 0.349 to 0.048 (NMDGF Files), with total bighorn population numbers ranging from 25-45. In November 1980, mountain lion control was initiated just prior to releasing a combination of 10 Arizona and 10 Red Rock bighorn into a paddock in the Peloncillos at the base of Gray Peak. The ewes were held for 7 months and the rams for 2 months as it was felt bighorn would have the best chance for survival if they were able to spend time in a confined area at the release site before being released into the wild. From November 1980 through June 1981, 8 mountain lions were removed from within 1 mile of the paddock, and an additional 14 were removed (for depredation reasons) from the surrounding area. From 1980-1982, only 2 mountain lion kills were documented, both during 1982. It was hypothesized that bighorn loss to mountain lion predation would have been much greater without mountain lion control (Fisher1983).

In contrast, in the Big Hatchet Mountains no mountain lion control was initiated prior to the release of bighorn into a holding paddock in 1979. Within 6 months of releasing the bighorn from the paddock, 5 of 12 bighorn were missing, with 2 confirmed mountain lion kills. Only 2 mountain lions were removed that fall and the population increased very little until a second augmentation in 1982. Eighteen bighorn were released in December 1982, and 5 of 18 were killed by mountain lions within 2 months of the release. Later that winter, 4 mountain lions were removed (Sandoval 1983). Subsequently, the population increased until there were over 80 individuals during the mid to late 1980s.

Despite evidence that proactive mountain lion control is beneficial to desert bighorn herds, NMDGF prohibited removing mountain lions for desert bighorn restoration. In 1997, selective control of predators that had killed a bighorn (also known as an offending mountain lion policy) was allowed. By 1997, after the deployment of 78 radiocollars on bighorn in the Sierra Ladron, Fra Cristobal, and San Andres populations, it was documented that mountain lion predation was the primary cause of adult mortality in desert bighorn sheep in New Mexico (Sandoval 1980, Hoban 1990, Rominger and Weisenberger 2000). In an effort to increase the ability to cull offending mountain lions, NMDGF increased aerial monitoring of radiocollared bighorn. In addition, in 1999, 58 desert bighorn sheep were radiocollared (27 rams from Red Rock and 31 extant ewes). Although a limited number of offending mountain lions were harvested in the Peloncillo, Fra Cristobal, and Ladron Mountains, the effort was not sufficient to mitigate the statewide decline in desert bighorn.

A management project was designed to test the effectiveness of increased mountain lion harvest on survival rates of adult radiocollared bighorn in 4 bighorn sheep ranges (Rominger and Dunn 2000). An increase in the mountain lion quota in 3 desert bighorn sheep ranges (Peloncillos, Hatchets, Ladrons) was implemented in an effort to increase sport harvest of mountain lions in these ranges. This liberalized hunting quota resulted in no increase in the number of mountain lions harvested in these ranges. In 1999, NMDGF contracted houndsmen to work 80 hours/month in these ranges. No mountain lions in excess of the quota were taken, and only 2 sport harvested mountain lions were removed in desert bighorn range. In 2000, 2001, and 2002 mountain lions were responsible for 73%, 75%, and 69% of radiocollared desert bighorn mortality, respectively (NMDGF Mortality Tables 2003). In 2000, NMDGF offered

$2,000/mountain lion harvested to a contractor in each of the 3 ranges. NMDGF paid for no mountain lions during 2000. In 2001-2002, NMDGF again offered $2,000/mountain lion harvested to 4 different contract hunters (3 houndsmen in the Peloncillo and Hatchet Mountains, and 1 snareman in the Ladron Mountains). This resulted in the harvest of 7 mountain lions in the Peloncillos, 3 mountain lions in the Hatchets, 10 mountain lions in the Ladrons between December 2001 and May 2003, and 15 mountain lions in the San Andres between October 2002 and May 2003. In addition, in April 2002 a second permit was granted to public mountain lion hunters to be used only in desert bighorn ranges, and mountain lions taken in desert bighorn ranges no longer count against the mountain lion harvest quota. It is too soon to evaluate the efficacy of this program on protecting bighorn sheep herds.

The mountain lion removal program is designed with an adaptive management approach. As the number of bighorn sheep increases and the percent of bighorn killed by mountain lions decreases, the number of mountain lions harvested to protect bighorn will decrease. For example, in the San Andres Mountains, mountain lions were removed for 2 months before the 2003 bighorn sheep release, and 3 months after the release. According to the mountain lion removal plan, at the end of the 5 month period, mountain lions would be removed based on an offending mountain lion policy only until the bighorn herd reaches a total of 200 individuals with a minimum of 100 ewes, at which point mountain lion removal would end (USFWS 2002). According to the VORTEX modeling [see *Supply*], 5% additive annual mountain lion caused mortality would cause all bighorn populations in New Mexico to go extinct. Therefore, if mountain lions kill 5% of the bighorn population within any 12 month period, mountain lion removal would resume for 6 moths or through the month of May (the majority of kills occur between December and May), whichever is longest. With this adaptive management approach, mountain lions may be intensively removed at first to allow the bighorn population to establish itself. Removal becomes progressively less intensive as long as mountain lions are not predating on bighorn sheep at a rate that pushes bighorn towards extinction. However, if monitored mountain lion predation rates on bighorn sheep increase to where the bighorn population may be negatively impacted, then more intensive removal resumes. By closely monitoring the bighorn herd we are able to remove lions at a level to promote bighorn growth without removing more mountain lions than necessary to achieve this goal.

Predator control is advocated when ungulate populations are below carrying capacity, when predation is a limiting factor, when control occurs at a focused scale, and when the removal effort is large enough to yield results (Ballard et al. 2001). Ernest et al. (2002) found that removal of 1-2 mountain lions per year decreased extinction risk for bighorn populations consisting of 15-30 ewes to less than 15%, whereas removal of 3-4 mountain lions was necessary to decrease extinction risk for bighorn populations containing less than 15 ewes. In addition, they demonstrated that removing any mountain lion found in bighorn range was more effective at saving bighorn than removing mountain lions known to have killed bighorn sheep. This was especially true for populations with less than 10 ewes remaining. In New Mexico, the goal is not to merely minimize extinction risk but to increase state-wide population numbers of this endangered species, therefore additional removal is warranted. As long as mountain lions are able to prey switch onto other prey sources, especially exotic ungulates that artificially maintain

mountain lion numbers at elevated levels, removal is warranted to return their numbers to levels compatible with the wild prey base.

If a population grows to greater than 100 with a minimum of 50 ewes NMDGF will consider using the wild population for transplant stock. However, NMDGF will continue to remove offending lions until the bighorn population reaches 200 animals with a minimum of 100 ewes. Allowing mountain lion predation to reduce the number of individuals in a desert bighorn herd helps prevent recovery of desert bighorn, and will likely result in the continued reduction in herd size. On the contrary, reducing the number of bighorn in a population by transplanting out of it allows the establishment of a new population with the potential to grow, while the original population should continue to expand. Thus, transplants will increase the number of desert bighorn populations, and should increase the number of individuals, in New Mexico and go towards recovering this endangered species.

Since 1999, annual mountain lion track surveys have been conducted in the Ladron, Hatchet, and Peloncillos Mountain ranges to obtain an index of mountain lion presence (Rominger et al. 2002). Mountain lions have been documented in each range in each year, however transects have not yet been monitored following years of substantial removal as the 2003 transects will be the first year of data collected following substantial removal. Optimally, these transects will provide an index of mountain lion density, though it is more likely that they will only reflect presence versus absence of mountain lions. These surveys will continue in an effort to monitor mountain lions and gain insight into the application of mountain lion sign survey data.

Cattle. Bighorn sheep compete for forage with domestic cattle when their ranges overlap (Gallizioli 1977). Bighorn may range into the flats during spring to obtain the earliest green forbs and during the rut, and cattle may range into rugged terrain if they cannot find enough forage in gentler terrain. In response to cattle, bighorn may spend more of their time in closer proximity to escape terrain, or even abandon ranges after cattle introduction (Bissonette and Steinkamp 1996). In recent research on reestablishing bighorn sheep metapopulations, the presence of cattle was negatively correlated with success of bighorn transplants (Singer and Gudorf 1999). In contrast to domestic sheep, cattle have not been implicated in causing bighorn die-offs nor has disease transmission from cattle to bighorn been conclusively shown. Cattle carry diseases that are a potential source of bighorn diseases (Jessup 1985, Onderka et al. 1988, McCarty and Bailey 1994, Singer et al. 1998). The gnat (*Culicoides variipennis*) vector has been documented to transmit the bluetongue virus between all ruminant species tested (Luedke et al. 1967), and fatal blue tongue outbreaks have been documented at Red Rock (Singer et al. 1998).

Perhaps most importantly in New Mexico, cattle grazing reduces fine fuels necessary to carry natural and prescribed fires, thus increasing woody vegetation density, cover, and distribution. Pinyon and juniper encroachment results in behavioral exclusion of bighorn and limits their visibility, making them more susceptible to predation. In many desert bighorn ranges, bighorn numbers are very low, as are deer numbers, yet mountain lion numbers remain high. It is hypothesized (Rominger et al. submitted) that beef calves may serve as an alternate prey source for mountain lions, thus artificially sustaining mountain lion populations as a subsidized predator *sensu* Soule et al. (1988). In Arizona, it was found that cattle and deer comprise 44% and 40%

of mountain lion diet, respectively. Deer were selected for less frequently, and cattle more frequently, than their availability within the habitat (Cunningham et al. 1999).

Domestic Sheep and Goats. Abundant evidence implicates domestic sheep as one significant cause of bighorn declines and extinctions from historical times to the present. Domestic and feral sheep use the same habitats as desert bighorn, compete for forage, and carry diseases that are lethal to desert bighorn sheep (Foreyt and Jessup 1982, Goodson 1982, Jessup 1985, McCarty and Bailey 1994). Pneumonia transmission from domestic to bighorn sheep usually results in high mortality, including all-herd die-offs. Domestic goats are considered a potential health threat to bighorn sheep (Jessup 1991), and were the apparent source of a pneumonia outbreak in the Hell's Canyon Rocky Mountain bighorn herd (Cassirer et al. 1996).

Although domestic sheep and goats do not free-range in currently occupied desert bighorn range, flocks of penned or free-ranging sheep in close proximity to desert bighorn are of concern. These include penned flocks in the Peloncillo Mountains, free-ranging domestic sheep and goats on the Alamo Band Navajo reservation adjacent to the Ladron population, and domestic sheep on the Jornada Experimental Range adjacent to the San Andres population. Feral goats in the Sacramento Mountains and domestic sheep in the Guadalupe Mountains currently preclude reestablishment of bighorn in these potential ranges. Penned or free-ranging flocks of domestic sheep or goats may impede recovery of desert bighorn sheep because they could insert disease into bighorn herds. It is NMDGF policy never to release a bighorn into the wild that is known or suspected to have come into contact with domestic sheep or goats.

Destruction to Prevent Disease Transmission. Fundamental to the recovery and protection of state species (and property), a bighorn should be destroyed to alleviate further damage to state property (17-2-42 (D) NMSA 1978). Rules will be promulgated in accordance with 17-1-14(15) and 17-2-42 to designate a process that would provide for the issuance of a permit to destroy a bighorn that has a high probability of having contracted an infectious or contagious disease by coming in contact with a domestic sheep or goat. This action is critical to the restoration and maintenance of desert bighorn (17-2-40.1 NMSA 1978), and would prevent an individual bighorn from returning to the wild herd and transmitting contagious diseases such as pneumonia that would likely induce a large scale dieoff. This type of action is consistent with the Commission's mandate to control, eradicate, and prevent the spread of contagious diseases among game animals (17-1-14(15) NMSA 1978).

Disease. Desert bighorn are more sensitive to diseases and parasites than other native big game species. Bighorn are particularly sensitive to diseases carried by domestic sheep and typically develop fatal bacterial pneumonia following contact (Goodson 1982, Jessup 1985, Foreyt 1989, McCarty and Bailey 1994) [see *Domestic sheep and goats*]. This is the basis of strict guidelines for separating wild and domestic sheep adopted by the Bureau of Land Management (Desert Bighorn Council Technical Staff 1998). In contrast, disease transmission from cattle to bighorn has not been conclusively proven [see *Cattle*]. Nonetheless, desert bighorn sheep are intensively examined and tested to avoid introducing infectious agents into new areas.

Disease problems may arise when bighorn herds with different disease histories are mixed. In 1981-1982 all Red Rock bighorn transplanted to the Peloncillo Mountains died of pneumonia following contact with co-released Arizona bighorn [see *Peloncillo Mountains*]. The potential for large die-offs from placing bighorn from different geographic locations in the same herd warrants considerable caution. Recent techniques developed at the University of Idaho enable scientists to evaluate disease profiles of animals from different herds, and may be useful in evaluating transplant options (Alton Ward, DVM pers. comm.).

Even though desert bighorn sheep in New Mexico have been exposed to many diseases of concern, only a few have been manifested in disease outbreaks. In Red Rock, bluetongue killed 22% and 15% of the herd in 1980 and 1991 respectively, and may have been responsible for a decline in 2000. Bluetongue is a noncontiguous viral hemorrhagic disease transmitted by biting gnats that have fed on infected hosts (Clark and Jessup 1992, Boyce 1994, Singer et al. 1998). The source of this host is unknown but may be sympatric deer, cattle, or both.

An outbreak of contagious ecthyma, a parapox virus that causes large scabs around the mouth, hooves, and genitalia occurred in 1980 at Red Rock (Blood 1971). This virus does not kill adult bighorn but it can kill lambs during severe outbreaks. It affected 12 bighorn (7 San Andres lambs and 5 Red Rock rams), and 2 lambs died. No adult San Andres bighorn showed symptoms of the disease (Ford 1980).

Chronic sinusitis is a bacterial infection that produces deterioration of bone in sinuses and horn cores and may be fatal (Bunch 1980). It is initiated by the deterioration of nasal bot fly *(Oestrus ovis)* larvae that hatch in the sinuses of bighorn sheep. This disease has contributed to the decimation of some bighorn populations (Jessup 1985). However, it does not appear to be common in New Mexico.

Chronic wasting disease (CWD) is a neurological disease that affects the brain causing proteins to fold abnormally and neural cells to die. Animals become emaciated, act abnormally, lose bodily functions, and eventually die. Recent experiments placing bighorn sheep in pens with deer and elk known to be infected with CWD have failed to transmit the disease to bighorn. Some cattle inoculated intracerebrally with CWD will contract the disease, but they fail to contract it by exposure alone (L. Bender, NMSU, pers. comm.). While CWD does not appear transmissible to bighorn, NMDGF tests all dead bighorn when a useable tissue sample can be obtained.

Elaeophorosis (*Elaeophora schneideri*) is a parasite that primarily infects mule *(O. h. hemionus*) and black-tailed deer (*O. h. columbianus*), though it has been reported in other ungulates (Boyce et al. 1999). The only reported incidence of this disease in desert bighorn sheep was a ram in the Fra Cristobal Mountains in 1997. This disease is characterized by the parasite residing in carotid and iliac arteries, and microfilariae in the skin, nasal mucosa, brain, and lungs. Lesions are observed on the head and face (Boyce et al. 1999). This disease is quite rare in bighorn sheep but it is possible for them to become infected with it.

Psoroptic scabies mites can be devastating to bighorn and have been implicated in the historic decline of desert bighorn sheep in the west (reviewed by Buechner 1960). In New Mexico, scabies appeared in 1978, reducing the San Andres population from 200 to 75 bighorn within a year (Sandoval 1980, Lange et al. 1980). Scabies mites feed on the animal's body fluids, causing the animal to lose patches of skin and to develop plugged, infected ears [see *San Andres Mountains*]. Currently no bighorn sheep in New Mexico are known to be infected with scabies.

Recent disease analysis of oryx revealed that these animals tested positive for several diseases that could pose a threat to native herbivores sympatric with oryx. Oryx showed a high prevalence of exposure to bovine respiratory syncytial virus, parainfluenza-3 virus, bluetongue virus, and malignant catarrhal fever, the latter of which is primarily a threat to cervids. No attempt was made to isolate of any of these agents from oryx to see if oryx were actively infected. However, oryx tested positive for *Pasturella trehalosi*, which can cause pneumonia in bighorn sheep. The biotype of *P. trehalosi* present is not generally pathogenic without presence of a predisposing condition such as stress, lowered body condition, or infection, none of which have been detected. While disease transmission from oryx to desert bighorn has not yet been clearly demonstrated, it does leave cause for concern. Therefore work is being done to further explore this issue (Bender et al. in press, Lou Bender, NMSU, pers. comm.).

Genetics. The establishment of Red Rock from a small number (22) of bighorn sheep, and the slow rate at which they increased, has lead to a genetic diversity approximately 60% lower than found in wild desert populations (Gutierrez-Espeleta et al. 1998). Low genetic diversity is associated with high mortality, lower reproduction, greater susceptibility to disease, and reduced competitive ability (Allendorf and Leary 1986, Ralls et al. 1988). Red Rock is currently New Mexico's sole transplant source, therefore genetic diversity throughout the state may be compromised. Transplanting bighorn from outside sources should increase genetic diversity and potentially reduce mortality risks. Arizona bighorn have the highest genetic diversity, followed by Tiburon Island, Mexico, and lastly Red Rock (Hedrick et al. 2001, Boyce and Ostermann 2002). Addition of Arizona bighorn into New Mexico should be considered to increase heterozygosity, as should Tiburon Island bighorn as they have alleles not found in New Mexico (Gutierrez-Espeleta et al. 1998) and could increase allelic diversity of New Mexico bighorn.

Exotic Ungulates. Aoudads, also referred to as Barbary sheep, are native to North Africa, and were released in the Hondo Valley, Largo Canyon, and the Canadian River drainage between 1955-1970 (Ogren 1962). Viable populations have become established in historic bighorn habitat in the Guadalupe and Sacramento Mountains. Aoudads are occasionally sighted in desert bighorn habitats in the San Andres Mountains. They compete with desert bighorn due to their higher rate of increase, ability to subsist on lower quality forage, and preference for habitat similar to that of bighorn (Seegmiller and Simpson 1979). Aoudads are socially aggressive when they encounter bighorn and may disrupt the rut. The potential for aoudads to transmit diseases to bighorn is unclear. It is NMDGF policy to eliminate aoudads that occur in bighorn sheep habitat.

Persian wild goats, also known as ibex, were released in the Florida Mountains in 1970. Originally from Iran, they have been sighted in the Doña Ana Mountains 12 miles west of occupied range in the San Andres Mountains, and a skull was recovered in the Alamo Hueco

Mountains in 1997. Like aoudads, Persian wild goats are a potential competitor with desert bighorn sheep. A desert bighorn sheep, assumed to be from the Fra Cristobal population, was captured while running with a group of feral Caprids (Spanish goat/ibex crosses) on the Ladder Ranch in south central New Mexico in 1999. The potential for disease transmission exists, however Persian wild goats housed adjacent to desert bighorn sheep at Red Rock in the early 1970's were able to go nose-to-nose with desert bighorn with no documented disease transmission. Both aoudads and Persian wild goats are potential alternate prey items that may subsidize mountain lion populations to the detriment of native desert bighorn sheep. These species also occupy former desert bighorn sheep habitat, precluding reintroduction into those ranges.

Gemsbok, also referred to as oryx, were released onto WSMR between 1969 and 1977. Oryx, originally from Africa, have expanded their range into rocky foothills that overlap bighorn habitats in the San Andres Mountains and have moved into flat terrain on the periphery of bighorn habitat in the Fra Cristobal Mountains. Although oryx are unlikely to be major competitors with desert bighorn, the potential for disease transmission [see *Diseases*] and the possibility for oryx to be alternate prey for mountain lions exists. Oryx calves, hunter-wounded oryx, and oryx gut piles left by hunters may subsidize mountain lion diets, keeping the number of mountain lions in these areas artificially high. Oryx have been observed in high elevations (>6500') in the San Andres Mountains on a regular basis, overlapping with desert bighorn habitat. The Oryx Management Plan (NMDGF 2000) signed by NMDGF and WSMR recommends the reduction of oryx in bighorn habitat.

Deer. Both Coues' white-tailed deer and desert mule deer occur sympatrically with desert bighorn sheep. Although deer numbers are lower than in the recent past, they are hypothesized to be more numerous, at least during times of population highs, than they were historically in desert bighorn habitat (Berger and Wehausen 1991). This is primarily a function of increased deer habitat resulting from habitat changes induced by reduced fire frequency. Desert mule deer habitat use appears less likely to directly overlap bighorn sheep habitat than that of Coues' white-tailed deer, but in some desert bighorn ranges in New Mexico only desert mule deer have been observed.

Current deer densities in New Mexico desert bighorn habitat, based upon observation rates during helicopter surveys, are unlikely to represent a direct competition threat. However, if mountain lion control efforts are effective and deer populations increase the potential for direct competition must be reassessed. Deer were considered to be a major competitor in the Big Hatchet Mountains during the period of intensive mountain lion control in the early 1950's (S. P. Gordon, pers. comm.). Deer may share watering holes and mineral licks, may compete for limited forage during drought periods, and could be a potential source of disease (Singer et al. 1998). Water units installed for bighorn in previously arid areas may encourage deer use of bighorn habitat (Smith and Krausman 1988). In previously mountain lion-free bighorn ranges in California, resident mountain lions became established after the introduction of deer (D. Weaver, Cal Fish and Game, retired, pers. comm.). During periods of high deer density, deer may act as a buffer species protecting desert bighorn sheep. However, during periods of low deer density induced by drought, mountain lions at high density may prey-switch onto desert bighorn sheep as

has been documented in New Mexico (Rominger and Weisenberger 2000) and in other predator-prey systems (Seip 1992, Compton et al. 1996, Harrington et al. 1999). The ability of mountain lions to prey-switch and thus maintain high numbers may be inhibiting deer populations from recovering around the state (Logan et al. 1996).

Recreation. Desert bighorn sheep may be negatively affected by human-related disturbances. Desert bighorn may become habituated to vehicles and road traffic, however they are more sensitive to humans on foot (MacArthur et al. 1982, Papouchis et al. 2001). Recreational use probably is not harmful to bighorn if disturbances do not persist and occur infrequently. When bighorn are continually disturbed they may abandon habitat and water sources resulting in decreased numbers and distribution (Hicks and Elder 1979, Leslie and Douglas 1980, Hamilton et al. 1982, Papouchis et al. 2001). Increased recreational activity increases the potential for intentional human harassment and illegal kill.

Hunting. Unhunted populations in New Mexico generally have ram to ewe ratios of approximately 1:1 (Rominger 1999, 2000, 2001, 2002), and consequently there are more rams than required for breeding. Conservative hunting removes surplus rams from populations and may benefit herds by reducing excessive harassment of ewes during the breeding season. New Mexico's current bighorn sheep harvest strategy is designed to ensure a quality hunt, defined as one with low hunter pressure, high success rate, and good opportunity for harvesting trophy quality rams that score 168 Boone and Crockett points or better. The number of permits issued is based on population trends, ram to ewe ratios, total number of rams, and ram age structure [see *Demand*]. The objective is to retain a sufficient number of mature rams in the population to ensure adequate recruitment of younger rams. Desert bighorn are listed as a state endangered species with the exception of the Peloncillos population. Therefore, in accordance with the Wildlife Conservation Act, only the Peloncillos population may be hunted.

Mining, and Oil and Gas Exploration. Bighorn may temporarily abandon habitat while it is being mined, which could be critical if mining occurs on lambing grounds or near water sources. Roads for mining activities may provide access to previously undisturbed areas and increase negative impacts of people in bighorn habitat (McQuivey 1978). In the bootheel region of New Mexico, federal public land in the Big Hatchets and Alamo Huecos is withdrawn from oil and gas leasing, but much of the State Trust land in the area is already leased for exploration. Public land in other bootheel and south-central desert bighorn ranges has not been withdrawn from leasing. The Las Cruces Field Office of the Bureau of Land Management will examine and address mineral exploration and leasing issues in desert bighorn habitat through the Land Use Plan amendment process or in the upcoming Land Use Plan Revision (J. Barnitz, BLM, pers. comm.). The area from the Ladron Mountains to the Devil's Backbone in the Magdalena Mountains is currently open, but the Bureau of Land Management is working to reduce the size of the area that is open, and to restrict broad scale seismic activities in favor of site-specific ones (D. Heft, BLM, pers. comm.).

Illegal Harvest. Illegal harvest of rams and ewes has been documented in most of the state's populations (NMDGF Mortality Tables). Increased public awareness of bighorn poaching followed the widely publicized killing of 2 rams in the Ladron Mountains shortly after their

release in 1992 (Knadle 1993). Relative impacts of poaching on a population depend on which sex is taken. Illegal harvest of rams decreases the ram:ewe ratio and availability of rams for future legal harvest. Additionally, black market trophy hunting may increase as populations increase in size and distribution. Unless all mature rams are taken, illegal ram harvest does not significantly impact population persistence. In contrast, ewe harvest can quickly cause a population to decline because of the intrinsically low reproductive rate of bighorn sheep.

Manmade Barriers. Barbed and net-wire fences are hazardous to desert bighorn because they restrict movement and cause mortality. Bighorn will crawl through and jump over fences, but they are poorly adapted for jumping due to their stocky build and may die if they become entangled (Helvie 1971, Welsh 1971, Elenowitz 1983). Two and 4-lane highways may inhibit movement and cause mortality from accidents. None of the 33 radiocollared bighorn released south of I-10 in 1997 and 1999 in the Peloncillo Mountains has been observed north of I-10. Housing and other land-use developments also disrupt travel corridors and fragment use of desert mountain complexes by metapopulations. An abundance of public lands limits housing development in most desert bighorn habitat, but increasing development is apparent on private lands on the western side of the Peloncillo Mountains near Rodeo, New Mexico. As the state's human population increases, urbanization will encroach further into desert bighorn habitat.

Weather. Weather, specifically annual precipitation, may cause population fluctuations in bighorn sheep. In the Hatchet Mountains and Alamo Hueco populations, wet years corresponded with high lamb survival whereas low lamb survival during drought years were observed (Fisher 1991). Drought conditions may contribute to a reduction in quality and quantity of forage, increased predation rates if there are fewer alternative prey sources, increased vulnerability to predation at watering sites, and an insufficient quantity of drinking water, all of which could contribute to population declines. Adult mortality during droughts has not been documented in New Mexico, although low lamb:ewe ratios have been documented during drought years.

❖ Summary and Conclusions

In the last decade, New Mexico has developed a very active desert bighorn sheep management program. From 1992-2002, NMDGF conducted 6 transplants from Red Rock, releasing 156 bighorn to establish new populations or augment existing populations. Including bighorn from Red Rock, a total of 226 desert bighorn sheep were radiocollared from 1992-2002. From 1995-2002, desert bighorn were hunted in the Peloncillo Mountains. Since 1997, NMDGF has conducted annual public information meetings on desert bighorn sheep in 2 areas of the state. As of 2003, 7 prescribed fires specifically for desert bighorn sheep have been conducted in New Mexico. In 1999, the Turner Endangered Species Fund sponsored a Population Viability and Habitat Workshop with the Conservation Breed Specialists Group on New Mexico desert bighorn sheep (Fisher et al. 1999). Research projects on lambing habitat, cause-specific adult mortality rates, fire, disease, biological extinction, and lamb mortality have been conducted (Boyce et al. 1999, Singer et al. 1999, Rominger and Weisenberger 2000, Arana 2001, Bangs 2002, Parsons in prep, Rominger et al. submitted). Thirty-six mountain lions were removed by contract hunters in desert bighorn range from October 2001 through July 2003.

One hundred bighorn within a population or metapopulation is considered the minimum number for long-term survival based on Berger's (1990) analysis that populations of this size persisted for up to 70 years. Small populations are more vulnerable to extinction than are large populations. However, recent information suggests that many populations numbering less than 50 bighorn have survived for more than 50 years (Wehausen 1995), indicating that populations of this size may be worth establishing especially if they are part of a larger metapopulation. Small populations of desert bighorn sheep may be integral to the recovery of desert bighorn sheep throughout their distribution (Krausman and Leopold 1986). Throughout the west, successful transplants of bighorn sheep have averaged 41 individuals (Singer et al. 2000). Griffiths et al. (1989) suggests transplanting 20 to 40 individuals when working with large ungulates, and releasing additional animals does little to increase transplant success. In addition, they suggest that the inflection point at which the number of animals transplanted does little to increase transplant success is based on the threshold population size below which extinction is likely. In New Mexico, this extinction threshold will be largely based on the level of mountain lion control, as it is the predominant cause of mortality. The number of bighorn in an initial release and the decision to augment a herd will be based on levels of mountain lion control, demographic structure, and growth of the individual bighorn sheep herd. The determination of which herd to augment or where to establish a new population will be made after considering the demographics and condition of existing herds, and release site characteristics as described under *Special Considerations*. In order to promote genetic diversity and increase the likelihood of naturally restocking the populations, it might be beneficial to create a metapopulation structure by linking the New Mexico, Arizona, and Mexico populations. Movement corridors between populations may greatly contribute to perpetuation of these populations in the future.

This recovery plan outlines strategies for NMDGF and cooperating agencies to increase the numbers and distribution of desert bighorn sheep in New Mexico so they may be removed from the state list of threatened and endangered wildlife. Specific criteria for downlisting and delisting desert bighorn sheep under the WCA are based upon statutory definitions of "threatened" and "endangered" described within the WCA (17-2-38 NMSA 1978). The criterion for down-listing to threatened status is a minimum of 250 free-ranging desert bighorn sheep in at least 2 geographically distinct populations or metapopulations, each containing at least 100 bighorn. The criterion for removing desert bighorn from the state endangered species list is a minimum of 500 free-ranging desert bighorn sheep in at least 3 geographically distinct populations or metapopulations, each containing at least 100 bighorn.

❖ Public Involvement

A draft of this plan was posted on the NMDGF website with a request for comments from April-July 2003. Public meetings were held in Albuquerque, Lordsburg, Silver City, and Las Cruces in April 2003 to discuss a draft of this plan and establish a Desert Bighorn Sheep Advisory Committee. An invitation to this meeting, along with the website address for the draft plan, was sent to 26 Federal Agency biologists, 46 private individuals, 6 County Commissions, 16 sportsmen's groups/outfitters, 19 wildlife/environmental groups, and 27 ranchers. Thirteen people were appointed to the Advisory Committee. We received comments from 5 members of the Committee, 3 members of the public, and one State Game Commissioner.

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❖ Management Goal and Objective

Goal: That New Mexico's desert bighorn sheep exist in sufficient numbers and distribution to warrant removal from the state-endangered species list.

Objective: To have a minimum of 500 free-ranging desert bighorn sheep in at least 3 geographically distinct self-sustaining populations or metapopulations, each of which contains at least 100 bighorn, and to delist the subspecies under the New Mexico Wildlife Conservation Act at that time. As an interim step to achieving this objective, desert bighorn sheep should be downlisted to "threatened" when a minimum of 250 free-ranging desert bighorn sheep exist in at least 2 geographically distinct populations or metapopulations, each containing at least 100 bighorn.

❖ Management Issues, Opportunities, and Strategies

Management issues that need to be addressed to attain this plan's management objective are listed below. Recommended strategies follow each problem. Problems and strategies are grouped into 2 categories. The first category contains issues and strategies that are critical to bighorn recovery. The items in the second category are important for bighorn recovery but may or may not be addressed within the timeline of this plan.

CATEGORY 1

ISSUE 1. Brush encroachment has resulted in a significant loss of bighorn habitat, reduces visibility for bighorn sheep, and hinders their ability to visually detect predators and escape from predation.

Strategy 1. Work with land management agencies, private landowners, and private organizations to control tree/brush encroachment by cutting woody vegetation, prescribed burns, and with other methods.

Strategy 2. Work with land management agencies, private landowners, and private organizations to create grassbanks for cattle use to allow growth of fine fuels on lands on and adjacent to bighorn sheep habitat.

Strategy 3. Use GIS and historical aerial photos to develop models of habitat change in both occupied and unoccupied desert bighorn sheep ranges to aid in restoration of these habitats.

Strategy 4. Reduce and maintain reduction of woody vegetation surrounding water catchment units placed for bighorn sheep.

ISSUE 2. Predation is a significant mortality factor in all desert bighorn herds.

Strategy 1. When establishing new herds, transplant a minimum of 30 ewes and female yearlings, and 10 rams to compensate for initial high predation rates and supplement existing herds until they are large enough to be self-sustaining [see *Summary and Conclusions*].

Strategy 2. Minimize access of bighorn sheep predators to Red Rock and remove those that gain entry.

Strategy 3. Conduct preventative mountain lion control by removing mountain lions from bighorn range for a minimum of 3 months prior to transplanting bighorn to a given location. This will be particularly important when translocating bighorn from habitats that have few or no mountain lions, e.g., Tiburon Island or Kofa Mountains.

Strategy 4. Implement policies and practices that allow removal of sufficient mountain lions within desert bighorn sheep range to ensure that mountain lion predation does not preclude establishment of self-sustaining desert bighorn populations. Then remove offending mountain lions from bighorn ranges until the herd is large enough to withstand predation without compromising the herd.

Strategy 5. Radiocollar all transplanted bighorn. Have a full time monitor tracking bighorn and a mountain lion hunter removing mountain lions. Offending mountain lions should be removed as soon as they are identified and detected. This should continue until the bighorn population is large enough to withstand predation without compromising the herd.

Strategy 6. Keep a minimum of 25% of the statewide desert bighorn sheep population radiocollared, and monitor all bighorn during fixed-wing and annual surveys to better understand causes and patterns of mortality.

Strategy 7. Conduct mountain lion monitoring in critical desert bighorn sheep ranges to better identify and remove offending mountain lions. Once herds are large enough to sustain mountain lion predation without compromising the herd, radiocollar and monitor mountain lions within these bighorn ranges to improve our understanding of mountain lion biology including movement patterns, diet, and general population dynamics. Coordinate with other agencies and landowners to support this research.

Strategy 8. Sudden large reductions in alternate prey species may temporarily greatly increase predation rates on desert bighorn sheep. Increased mountain lion harvest and decreased deer harvest may be required during drought years that reduce deer numbers, or when cattle that may be subsidizing mountain lion populations are removed from large portions of the habitat.

Strategy 9. Develop public understanding and support for NMDGF management of bighorn and predators in bighorn ranges.

Strategy 10. Continue to model cause specific mortality rates for radiocollared desert bighorn sheep.

ISSUE 3. Bighorn sheep do not readily disperse to establish resident populations at new sites and the desert bighorn program objective cannot be realized unless established populations become viable and self-sustaining.

Strategy 1. Transplant bighorn sheep to all suitable ranges in New Mexico, where it is biologically, economically, and politically feasible, and where conditions could be made favorable for their success.

Strategy 2. Augment these populations until they are self-sustaining [see *Summary and Conclusion*].

Strategy 3. Re-establish a metapopulation in the San Andres and adjacent Organ and Oscura Mountains to potentially support up to 650 desert bighorn sheep.

Strategy 4. Maintain a viable Bootheel metapopulation consisting of a minimum of the Hatchet, New Mexico Peloncillo, and Arizona Peloncillo populations.

Strategy 5. Transplant only *O. c. mexicana* in areas currently or historically occupied by the *O. c. mexicana* subspecies in order to conserve genetic diversity.

ISSUE 4. The Peloncillo Mountains are highly skewed towards males (an estimated 7 ewes and 20 rams).

Strategy 1. Work with landowners and other agencies to augment the number of bighorn, especially ewes, in the Peloncillos.

Strategy 2. Employ methods to change the ewe:ram ratio in favor of ewes, such as transplanting additional ewes to the Peloncillos and hunting rams.

Strategy 3. Retain the Peloncillo hunt as a management tool.

ISSUE 5. Free-ranging populations of desert bighorn in New Mexico are too small to sustain removals to establish or supplement other populations.

Strategy 1. Continue to operate Red Rock to propagate desert bighorn sheep for restoring desert bighorn in New Mexico.

a) Develop ways to improve the fence surrounding the pens, such as (but not limited to) replacing damaged or worn parts of the fence, hot-wiring the entire fence, and keeping the fence apron buried.

a) Monitor desert bighorn sheep range condition, production, survival, numbers, and sex and age ratios.

b) Conduct thorough investigations of disease outbreaks.

c) Maintain no more than 140 animals, and no less than 20 adult and yearling ewes.

d) Maintain a ratio no higher than 100 rams per 100 ewes.

e) Continue the supplemental feeding program year-round to mitigate potential problems associated with over-grazing.

f) Increase genetic diversity in Red Rock by adding new individuals from Arizona and or Mexico into the population after resolving disease transmission concerns.

g) Capitalize on the research potential of a captive herd by having technicians and/or students at Red Rock to test scientific hypotheses to further our understanding of desert bighorn ecology.

Strategy 2. Meet external demands for captive bighorn by developing a plan for the transfer of bighorn injured during capture operations to a zoological facility.

ISSUE 6. Adequate scientific information may not exist to enable managers to fully understand the biological variables associated with bighorn sheep management.

Strategy 1. Support research projects in New Mexico and in conjunction with other states to answer questions including but not limited to bighorn/habitat interactions, bighorn/livestock interactions, mountain lion/livestock interactions, bighorn/predator interactions, effects of prescribed fire on bighorn sheep, disease and health issues, physiology, diet, behavior, genetics, and population dynamics.

ISSUE 7. Diverse interests of the general public, land management agencies, private landowners, and other affected groups or individuals may conflict and impede attaining the desert bighorn program objective.

Strategy 1. Preclude conflicts and increase support by involving those who may be affected in planning and implementing bighorn program strategies.

a) Continue to conduct Public Information Meetings and/or Advisory Committee Meetings annually to solicit input and discuss ideas pertaining to desert bighorn management. Minimally, representatives from land management agencies, wildlife interest groups, individual landowners, sportsmen's groups, and livestock organizations should be invited to attend.

b) Involve publics and other agencies at early stages when discussing new project ideas.

Strategy 2. Develop educational programs about bighorn sheep biology, behavior, current relationship with predators, and habitat requirements for presentation to schools and other interested groups.

ISSUE 8. Diseases and parasites carried by domestic sheep and goats are lethal to bighorn sheep and have caused widespread die-offs.

Strategy 1. Do not transplant bighorn sheep into areas where they may be expected to contact domestic sheep or goats.

Strategy 2. Never release a bighorn suspected of contacting domestic sheep or goats back into the wild until such a time that laboratory tests exist that can positively identify if that bighorn will pose a health risk to other bighorn.

Strategy 3. Work with land management agencies and private landowners to reduce contact between domestic sheep and goats and established populations of bighorn sheep, and to prepare new ranges for future bighorn releases.

Strategy 4. Seek Commission approval for rules that would help prevent disease transmission from domestic sheep and goats to bighorn, such as by issuing a kill permit, if appropriate, to destroy a bighorn that has a high probability of having contracted an infectious or contagious disease by coming in contact with a domestic sheep or goats. This would prevent the bighorn from returning to and infecting other wild bighorn in the herd.

ISSUE 9. Certain diseases and parasites can negatively impact both bighorn sheep and domestic livestock.

Strategy 1. When handling bighorn, sample for the presence of diseases of mutual concern to NMDGF and the livestock industry as long as the disease screening is safe and reliable.

Strategy 2. Do not release bighorn of questionable health.

Strategy 3. Thoroughly investigate and, if feasible, treat disease outbreaks.

Strategy 4. Ensure that the establishment or use of water catchment units and salt stations does not create overlap between bighorn, deer, and cattle.

Strategy 5. Continue to monitor disease occurrences in bighorn.

ISSUE 10. The effectiveness of program strategies cannot be evaluated without monitoring progress toward the program objective.

Strategy 1. Intensively monitor population dynamics, distribution, and health of transplanted herds for a minimum of 6 months post-release, and annually after that.

Strategy 2. Monitor ram:ewe ratios and ram age distribution to determine harvest recommendations for hunted populations.

Strategy 3. Conduct studies as necessary to understand the dynamics and causes of population declines.

Strategy 4. Consult with this recovery plan to assure that management activities are consistent with it.

Strategy 5. Conduct a biennial review of this recovery plan to evaluate current conditions and species status.

ISSUE 11. Occupation of otherwise suitable bighorn sheep habitat by domestic sheep and goats, feral sheep and goats, and exotic ungulates threatens and/or precludes use by bighorn.

Strategy 1. Work with appropriate public agencies or private landowners on incentives to convert allotments from domestic sheep to cattle. Consider purchasing and retiring domestic sheep allotments.

Strategy 2. Work with appropriate public agencies or private landowners to remove feral goats and sheep in occupied or potential bighorn sheep range.

Strategy 3. Eliminate aoudad, Persian wild goats, and oryx when they are encountered within occupied bighorn range.

Strategy 4. Support the development of management plans for aoudad and Persian wild goats to clarify their management within potential bighorn range.

CATEGORY 2

ISSUE 12. Criteria for being a listed population are based on being an indigenous population. This is confusing because no populations in New Mexico are purely indigenous as they all have genes from individuals from Mexico, and some herds have genes from Arizona individuals.

Strategy 1. Change the listing to include all populations of *O. c. mexicana* in New Mexico, regardless of which state or country they originated from.

ISSUE 13. Opportunities exist to increase support for the program through recreational use of desert bighorn populations.

Strategy 1. Open hunting on state-wide desert bighorn populations once they have been downlisted or delisted and when surveys indicate that quality hunting would not affect population viability.

Strategy 2. Establish bighorn viewing sites in appropriate areas.

ISSUE 14. Game Protection Funds are inadequate to support the bighorn sheep program objective.

Strategy 1. Continue the annual auction of one bighorn sheep permit.

Strategy 2. Continue the annual raffle of one bighorn sheep permit.

Strategy 3. Continue to use additional sources of funding and volunteer assistance, available from the Habitat Stamp Fund, Federal Aid in Wildlife Restoration, private foundations, and sportsman groups.

Strategy 4. Continue to cooperate with federal agencies and other partners to jointly fund the bighorn management program.

ISSUE 15. Overlap of the same range by bighorn sheep and cattle could adversely affect bighorn sheep.

Strategy 1. Endorse bighorn sheep and cattle grazing management that will ensure habitat quality and discourage range overlap.

a) Work with land management agencies and private landowners to implement grazing practices that allow for fine fuel buildup needed for implementing prescribed burns, and a recovery period after the burn that may take several years.

b) Discourage range overlap by placing water for cattle in low elevations where bighorn are less likely to visit.

c) Place water catchment units for bighorn in areas where cattle are not capable of accessing them.

d) Work with land management agencies and private landowners to improve water distribution by developing and maintaining natural sites or installing water catchment units. Consider the potential adverse impacts of attracting predators, livestock, and deer with additional water units.

ISSUE 16. Illegal hunting may adversely affect population viability and black market hunting for horns may increase as larger rams are found in the resident populations.

Strategy 1. Reduce illegal kill through increased surveillance and education.

Strategy 2. Continue current regulatory strategies of banning the private possession of pickup skulls and requiring the sealing of hunter harvested ram horns.

Strategy 3. Work with NMFNAWS to offer reward for evidence resulting in conviction of any bighorn poaching.

ISSUE 17. Human impacts in or near bighorn sheep habitat may limit potential population growth or distribution.

Strategy 1. Work with land management agencies and private groups and individuals to find mutually acceptable ways to mitigate mineral, housing, and other developments.

a) Continue to keep paths of communication open to exchange information relative to all aspects of desert bighorn management.

b) Limit use during sensitive periods in critical areas.

c) Modify restrictive fences and construct new fences according to bighorn fence guidelines.

d) Work with land mangers to maintain unfragmented habitats, including travel corridors, to facilitate free movement of bighorn sheep within metapopulations.

e) Improve communication with the Transportation Department to increase our participation in planning the construction of roads, fences, guardrails, concrete barriers and other structures in desert bighorn sheep range.